

ELECTRONIC DESIGN

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SEPTEMBER 5, 1994

FOR ENGINEERS AND ENGINEERING MANAGERS—WORLDWIDE

COVER STORY P. 47

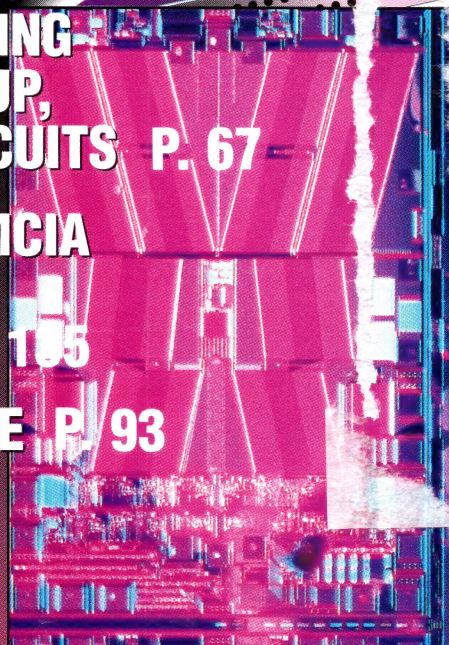
CHIP MANAGES POWER FOR DUAL PCMCIA CARDS

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5-V?
3-V?
12-V?

PLUG 'N PLAY

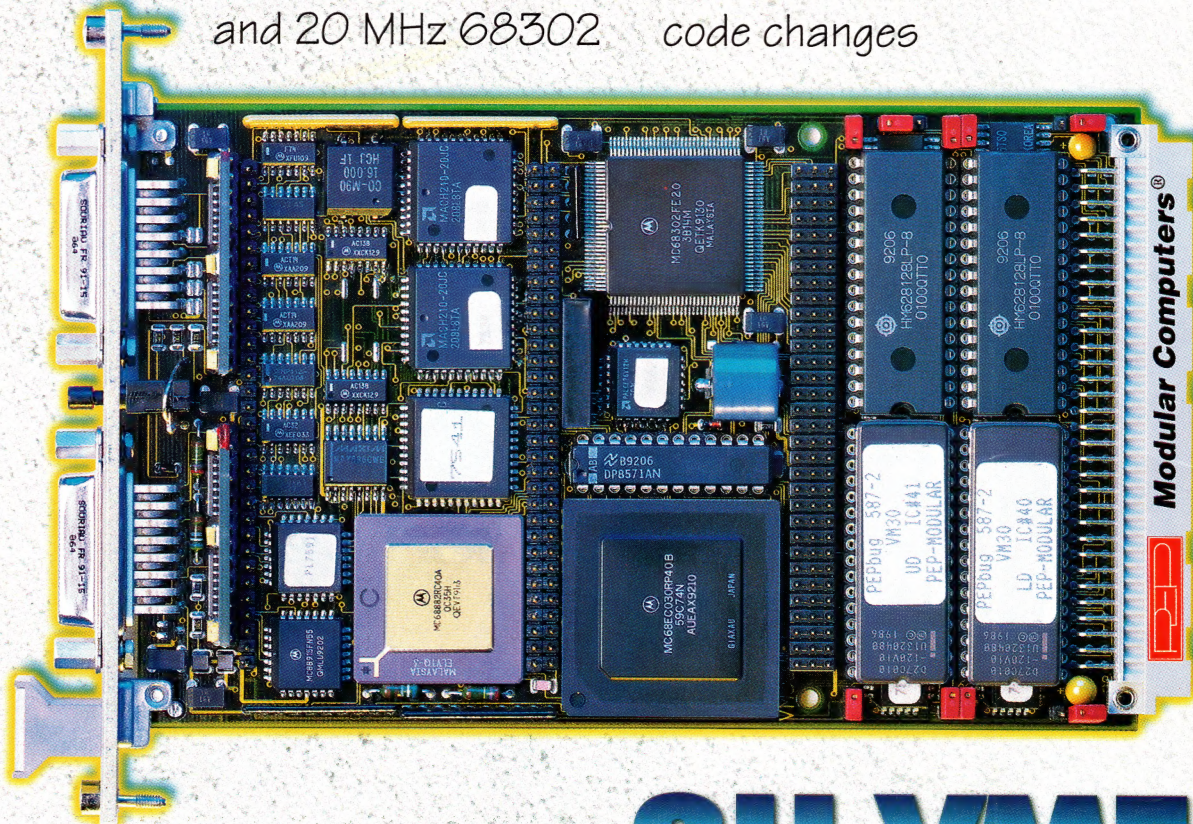
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▲ 1 MByte of 5V FLASH EPROMs enable swift code changes



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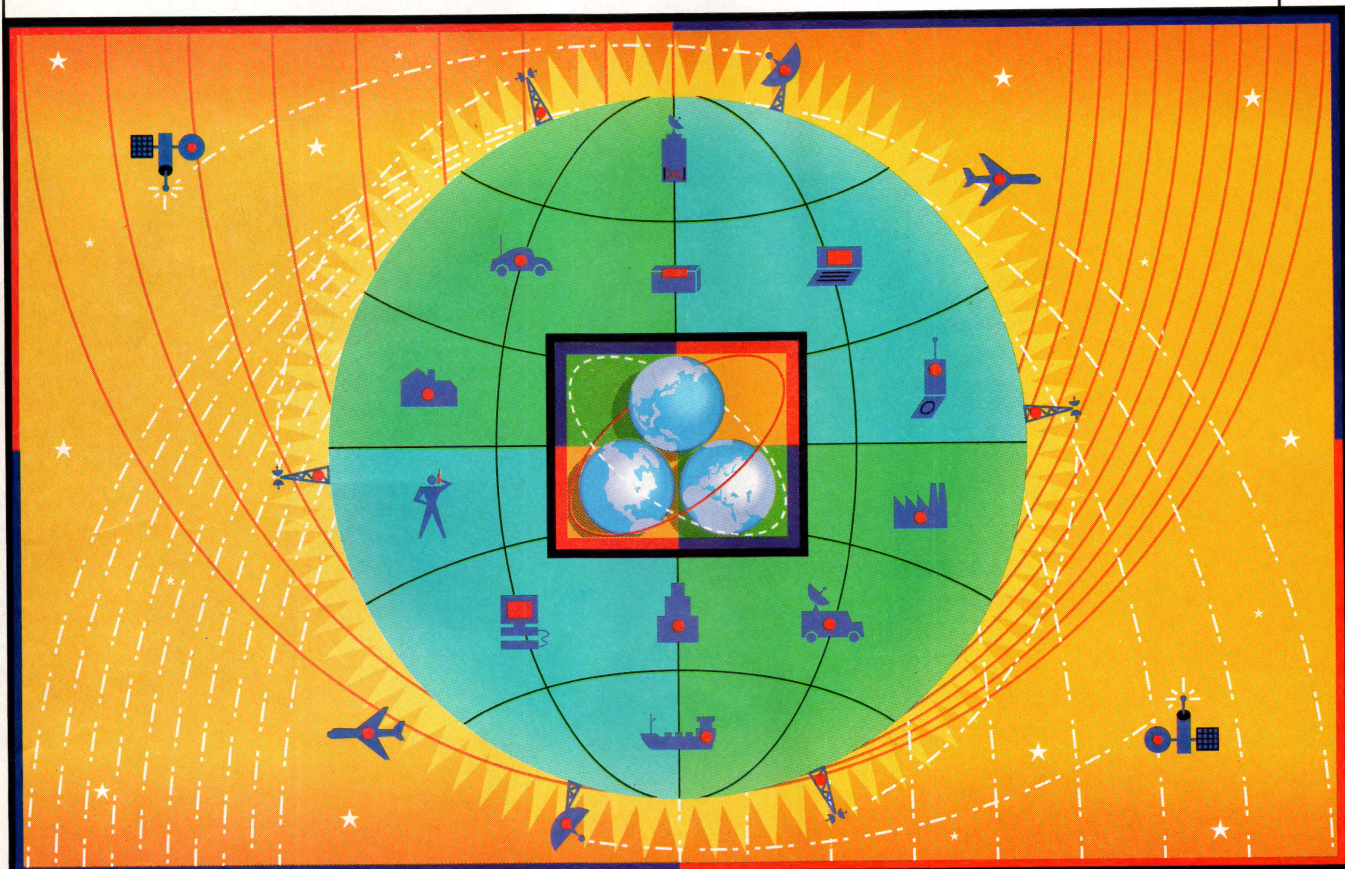
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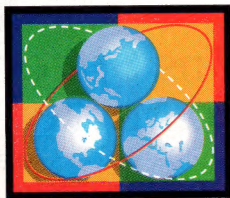
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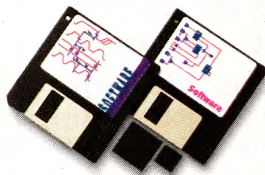
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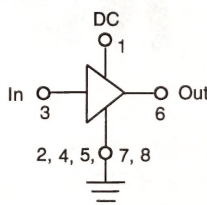
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**COVER
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HOST CPU'S IC MANAGES POWER FOR PCMCIA CARDS . . . 47

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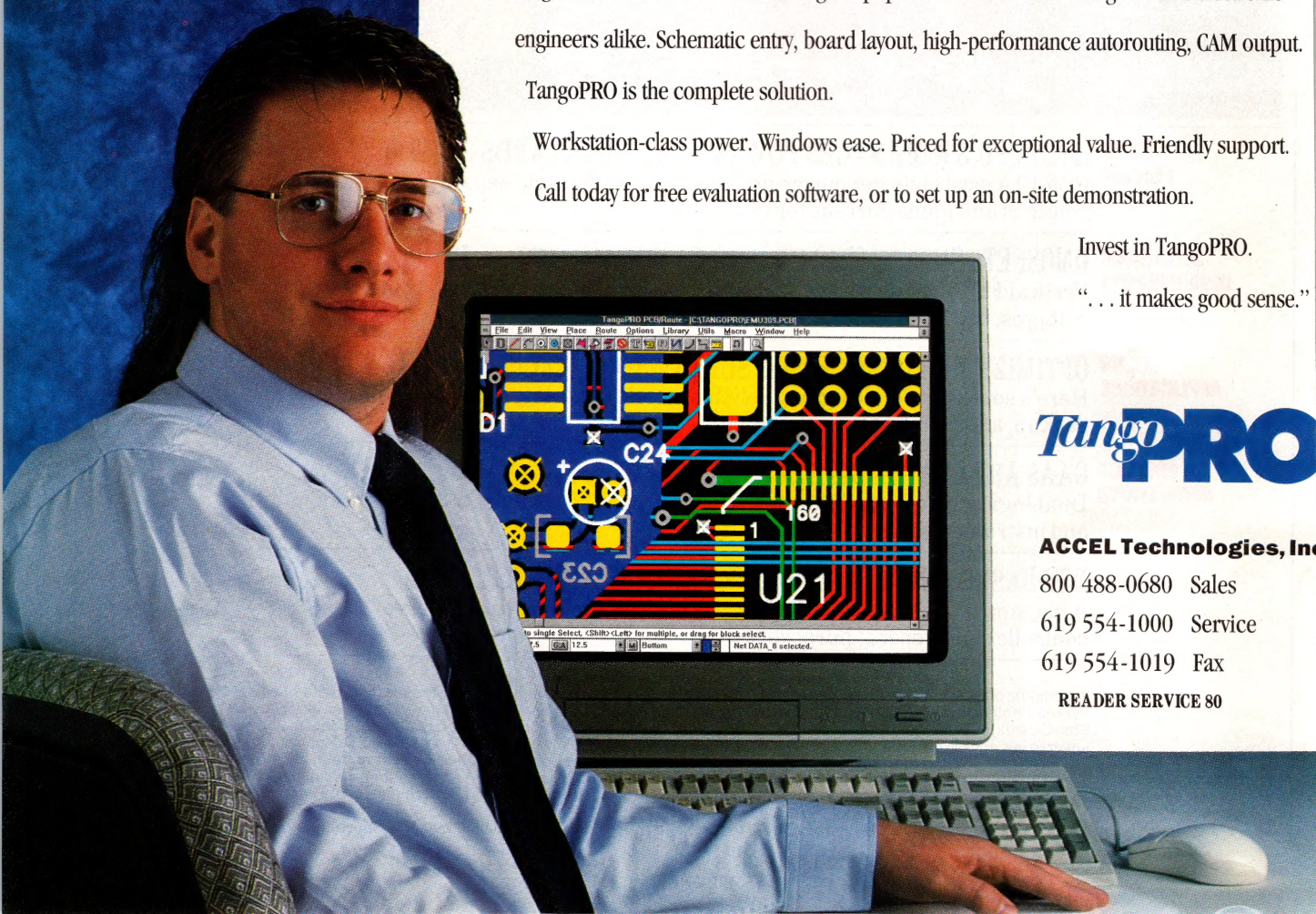
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ELECTRONIC DESIGN

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- First look at a 16-bit controller chip based on an 8-bit industry standard
- New architecture takes gate arrays to the next generation
- PLUS:
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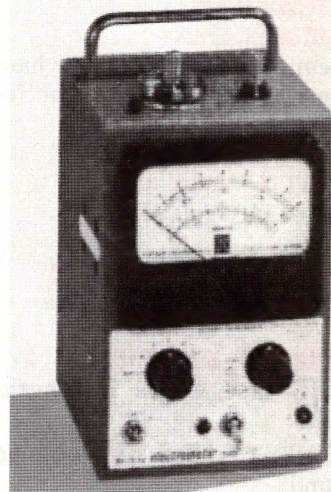
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ELECTRONIC DESIGN

40
YEARS AGO

Vacuum Tube Electrometer Has High Input Impedance

The Model 210 is a line-operated d-c vacuum tube voltmeter with an extremely high input impedance. Basic specifications include an input greater than 10^{14} ohms, grid current below 10^{-13} amp, and drift within 10 mV per hr. Five voltage ranges are provided: zero to 0.8V, 2V, 8V, 20V, and 80V, respectively, in either polarity. The electrometer has output terminals for driving balanced or unbalanced recorders, oscilloscopes, and galvanometers. The output amplifier drives the Esterline-Angus 0-1 milliamperere recorder directly, or delivers 10V out on each range for full-scale input. Frequency response of the output amplifier is 0-5000cy, making the Model 210 useful as a ultrahigh-input-impedance d-c preamplifier. The unit can be used not only as a d-c voltmeter, but as an extremely sensitive microammeter, megohmmeter, and kilovoltmeter. Maximum full-scale sensitivities are 8 x 10^{-13} amp, 3 x 10^{14} ohms, and 20,000V. Keithley Instruments, 3868 Carnegie Ave., Cleveland 15, Ohio. (*Electronic Design*, September 1954, p. 48.)



This is the instrument that put Keithley Instruments "on the map," according to company founder Joe Keithley. The company's first product was a battery-operated electrometer that, says Keithley, "sold enough to keep us encouraged." However, Keithley found that customers wanted two additional features: a recorder output and ac-line operation, which were included in the Model 210. Today, the company, which has grown to nearly \$100 million in annual sales, has just introduced its latest electrometer—the 6-1/2-digit, autoranging model 6517.—SS

TV of the Future

The television receiver of 1964 is envisioned as having a picture screen so thin that the complete unit could be hung on the living room wall like a painting. The circuitry would be built into the picture frame and would use printed wiring and miniaturized components. Controls would be located in a small box beside the viewer's chair. As explained by Dr. Lloyd T. DeVore, manager of the General Electric Company's Electronics Laboratory, the "picture on the wall" concept stems from a complex project to speed the plotting of aircraft in military filter centers. Development of speedier switching techniques and new fast-reacting phosphors are needed. (*Electronic Design*, September 1954, p. 5.)

Some things don't change: In 1954, the wall-TV was 10 years away. As each decade passed, it still was 10 years away. Anyone for 2004?—SS

TV-Phone Intercom

A telephone user can see the person with whom he is speaking by using the newly developed TV-Telephone Intercom System. When the person making the call lifts his handset, his image appears on one-half of the 17" TV screen. As soon as the called person answers, his image appears on the other half of the screen. Kalbfell Laboratories, Inc., San Diego, Calif., developers of the system, envisage a number of applications. Personnel identification and personnel interviews, inter-plant and inter-city conferences can be conducted by TV at considerable savings in time and money. When the telephone is not being used, the TV monitor can display regular broadcasts. The system features a vidicon pick-up tube with circuitry similar to this firm's standard TV camera, which has an 8Mc bandwidth and a horizontal resolution about twice that of standard TV receivers. (*Electronic Design*, September 1954, p. 10.)

Another great idea that's still on its way.—SS

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- FIFOs and Multi-Port Memories in ATM switches

III. Routers

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- Using Orion™ in a high-performance bridge/router
- A router for mixed voice and data traffic

IV. Portable Applications

- Components for PCMCIA cards
- A new highly integrated RISC CPU

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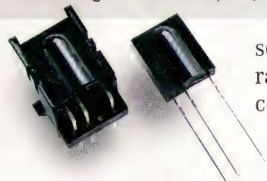
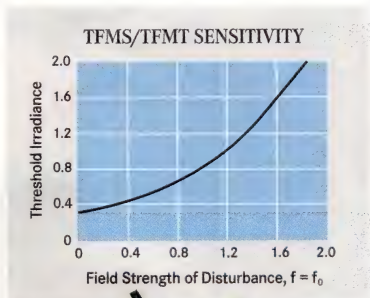
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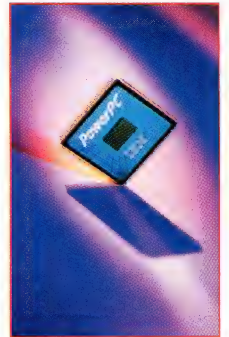
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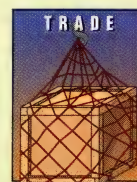
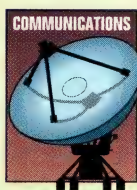
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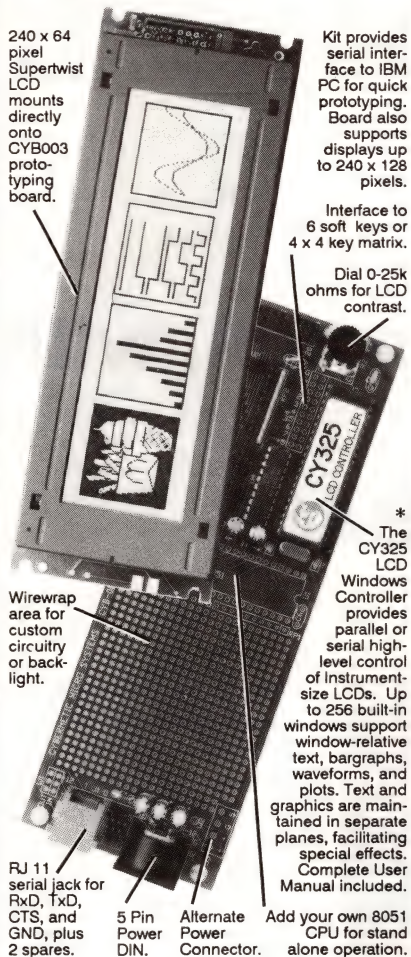
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EDITORIAL

FLAT-PANEL DISPLAYS

Of all the technologies deemed crucial to a nation's ability to compete in the fields of computers and communications, flat-panel displays present the most intriguing dilemma. On one hand, Japanese companies are so far ahead in their ability to manufacture active-matrix, liquid-crystal-diode displays (AMLCDs) that it seems foolish to do anything but partner with one of them, just as IBM has done with Toshiba Corp. A good corporate move, no doubt about it.

On the other hand, flat-panel technology is, in my view, a technology yearning to be reinvented. In a decade or so, a company that succeeds might well occupy the same dominant position that the Sharp Corp. now does with AMLCDs. The performance of AMLCDs fabricated on amorphous silicon has just about reached its limits. However, field-emissive displays (FEDs) demonstrate great promise for much better resolution and brightness. Other technologies hold hope as well.

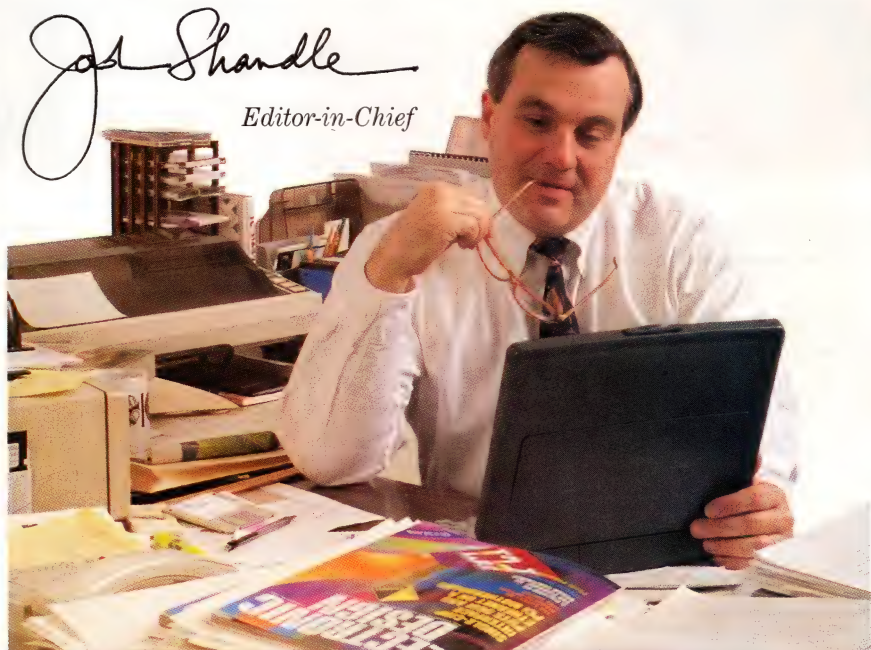
The problem with most alternatives is that an infrastructure must be created. FEDs, to cite one example, are based on cold-cathode devices that will not work with the phosphors developed for hot-cathode devices such as CRTs. So a whole new breed of phosphors have to be researched and developed in order to create realistic color.

This type of research is clearly an area in which government support can be helpful. That is, research that can take many paths, of which only a few are likely to work out.

I'm not surprised that the U.S. Department of Defense's recently announced decision to pump roughly a half billion dollars into flat-panel research drew some sharp criticism. I really thought the U.S. was firmly on the "dual-use technology" road and put to rest the red herrings like: "Pretty soon, we'll have a full-blown industrial policy," and, "We don't want the government to pick winners and losers."

Any nation that doesn't invest in flat-panel technology is going to be a loser in the international balance of trade. The most persuasive argument that I know for putting federal dollars into developing alternative flat-panel-display technology is the next level of integration. It's becoming possible to fabricate fairly complex chips on the periphery of the panel. And there's a real possibility that sometime in the future the display will be the computer.

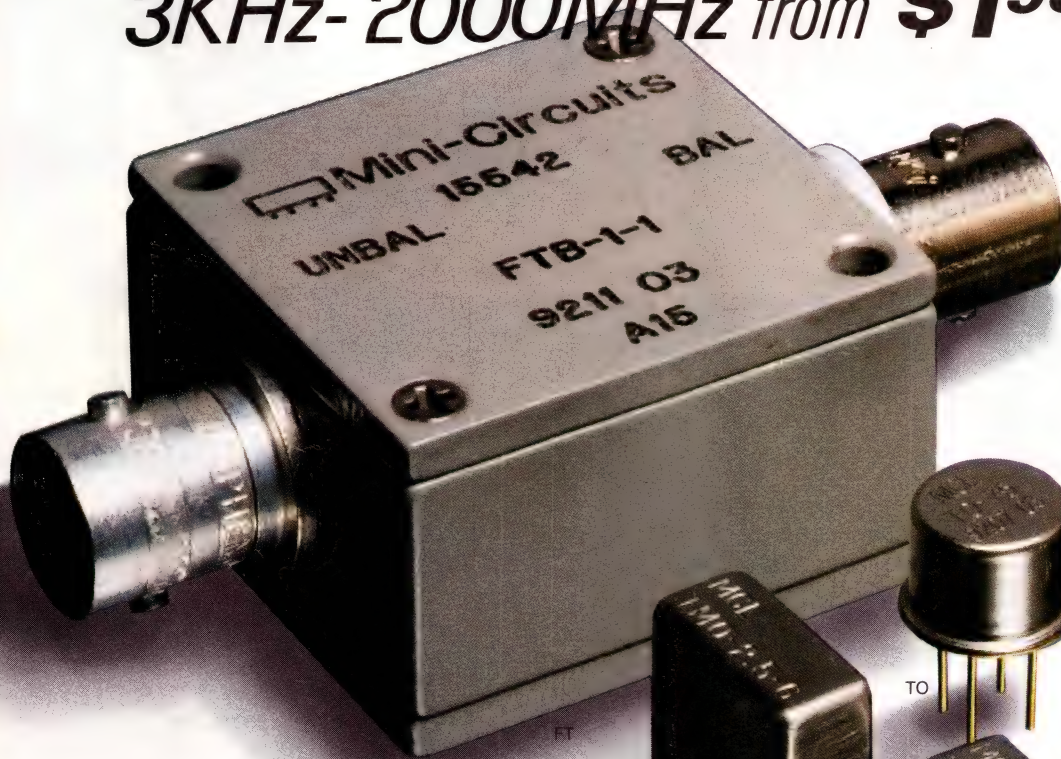
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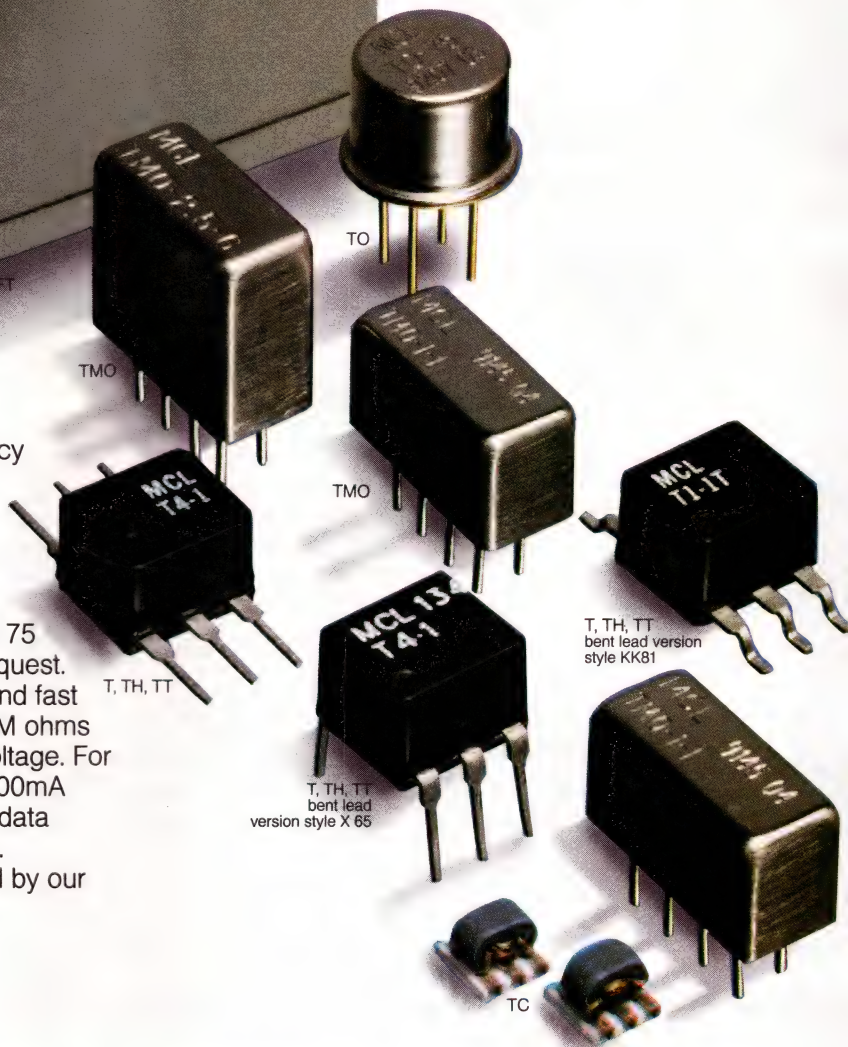
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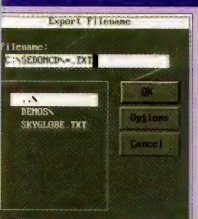
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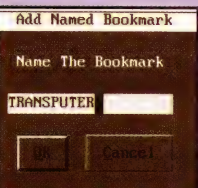
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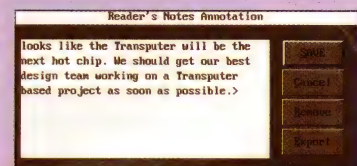
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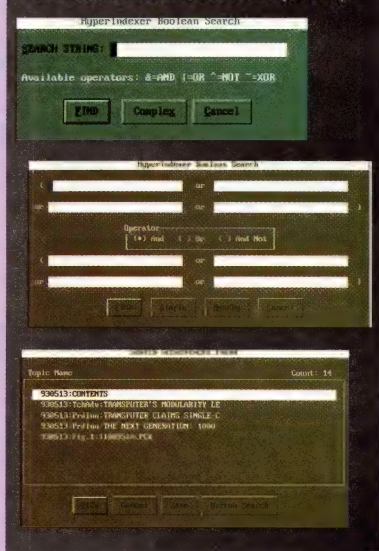
History Function	
Duration	Topic Name
19 Secs.	■ ELECTRONIC DESIGN ON CD-ROM:CONTENTS
2 Secs.	■ 930613:CONTENTS
26 Secs.	CLR : Clear Backboard Links
3 Secs.	930613:CONTENTS
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SEARCH dialog boxes

Simple search (top), Complex Search (center), and Search occurrences found (bottom).

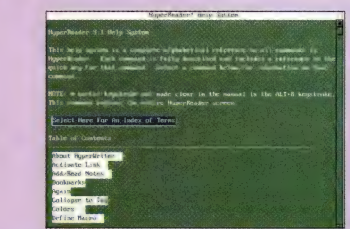


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TECHNOLOGY BRIEFING

DSP: THE KEY TO MULTIMEDIA

Once affordable only by government researchers, digital-signal processing has become a mainstay in every designer's multimedia toolkit and is invading virtually every product category. Advances in processing technology have managed to shrink the basic DSP function into a block on more complex chips.

The latest generations of computers and consumer-entertainment products owe many of their features to digital signal processing. The newer multimedia and video conferencing offerings, for example, have their roots in DSP chips or blocks that execute a variety of image compression/decompression algorithms. Multimedia audio and modems use programmable digital signal processors to provide flexible functionality and potential upgrade paths just by enhancing the control software.

DSP performance offers a wide range of options. At the low end, 16-bit chips or cells deliver throughputs of 20 million operations per second (MOPS), while high-end chips like the multimedia video processor developed by Texas Instruments Inc., Dallas, deliver over 2 GOPS thanks to on-chip parallel processing.

Reprogrammable DSP architectures deliver "functionality on demand" that results in multifunctional subsystems—cards that serve as a data modem, fax modem, phone answering system, and music playback-and-capture systems. Users need only download a different program. Simple 16-bit processors can readily handle what the industry now calls business audio, while high-end DSP chips will be able to perform real-time video compression/decompression.

Although DSP functionality has become a near necessity in many systems, it's the software controlling the digital signal processors that truly adds value. Algorithms and control programs that can incorporate the desired functions are essential to a system's features. However, to make the algorithms useful, there must be a broad base of applications and enough commonality across platforms to satisfy the needs of many users.

Standards organizations are working on baseline compatibility standards for JPEG, MPEG, video conferencing, and other applications. The computer industry also is proposing "standards" such as the Windows sound system. In fact, it's being promoted by Microsoft Corp., Redmond, Wash., as the de facto baseline for multimedia audio. The Windows sound system includes compression/decompression algorithms developed by the DSP Group Inc., Santa Clara, Calif., for its Pine DSP engine. Pine was created for telephone answering systems. Its Truespeech algorithms compress and decompress speech very efficiently, which saves disk space. In addition, the small size of the Pine processor core will allow designers to easily add hardware into more complex chips without creating expensive, large chips.

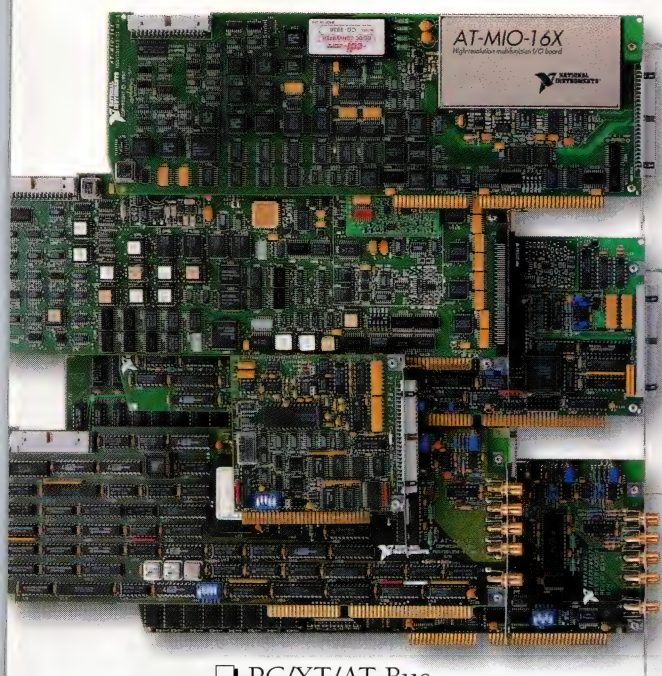
The alliance between the DSP Group and Microsoft has spread. Additional algorithm licenses are locked in with companies that have either licensed the DSP core, or plan to migrate the algorithms to their own DSP chip. Partners include Motorola Inc., Austin, Texas, and Silicon Systems Inc., Irvine, Calif., both of which have their own DSP engines; Integrated Computer Systems, Valley Forge, Pa., which will incorporate the Pine core into its audio circuits; and Compaq Computer Corp., Houston, Texas, which intends to embed the technology in its computers.

Although this kind of standard making is akin to a giant's cudgel, it does foster a level of compatibility and will provide a wide range of application interchange. For multimedia applications, that's just the remedy needed to assure users that applications in this immature market will at least be able to transfer files and use each other's information.

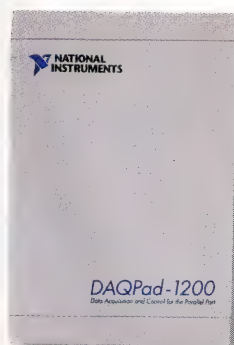


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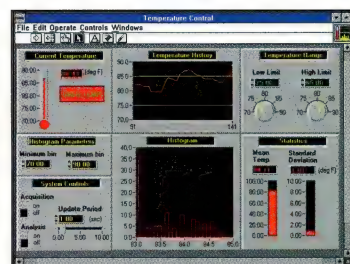
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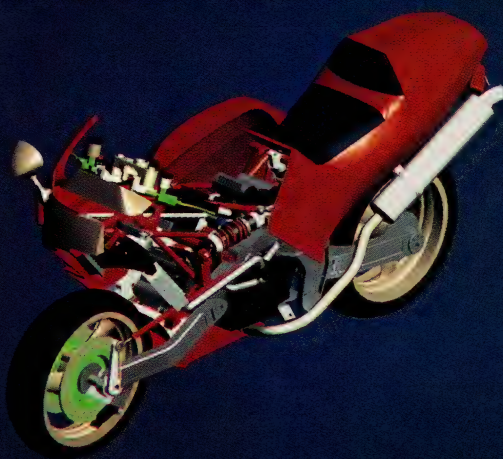
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NEWSLETTER

QIC TAPE GROWS IN LENGTH AND WIDTH

By increasing the width and length of a quarter-inch cartridge tape, Sony Corp., Park Ridge, N.J., extended the capacity of the tape by 61%. Called QIC-Wide media, the QW5122F tape is 0.315 in. wide, compared with the 0.25 in. of a standard tape. By using a sophisticated coating technology, the length of the tape was increased from 307 to 400 ft. As a result, the tape capacity jumps from 124 Mbytes to 200 Mbytes in native mode. The technology was co-developed by Sony and Conner Peripherals Corp., Costa Mesa, Calif. The tape was designed in conjunction with a tape drive called the TapeStor 400, which will be sold by Conner. The drive accepts either standard tapes or the QIC-Wide tapes. The new tapes have a lock-out mechanism that permits them from being used in older drives. For more information, call Conner at (714) 641-1230. *RN*

CELLULAR-STANDARD PROBLEMS ARE FOUND

The Telecommunications Industry Association (TIA) announced that several problems were discovered with the latest release of the IS-54 standard, which governs the operation of North American time-division multiple-access (TDMA) cellular telephones. System tests revealed several potential compatibility issues for operators attempting to use IS-54-A base stations to communicate with IS-54-B mobile equipment. For the most part, the problems were introduced during the transition from the previous version (IS-54-A) to the current version (IS-54-B). In all, 25 problems were identified involving such functions as calling-number delivery, call handoff and release, and access-channel boundaries determination.

The TIA developed a proposed resolution for each of these and published a technical service bulletin, TSB-47, which provides technical details of the interoperability problems and their proposed solutions. Available from Global Engineering Documents, Englewood, Colo., the TSB-47 costs \$38 and can be ordered by calling (800) 854-7179. *LG*

TALIGENT: A NEW ENVIRONEMNT

The Taligent application-development environment, a joint venture of Apple Computer, Hewlett-Packard, and IBM Corp., is one step closer to introduction now that IBM Corp. has implemented an early beta version of the development tools on its operating systems. An open, portable system, Taligent is built with a comprehensive set of object-oriented frameworks that allow developers to program more efficiently by reusing both code and design. The frameworks span functions, including user interface, multimedia, networking, communications, and data-access programs. Developers can use these frameworks as is, or use them as springboards to create new frameworks for their particular applications. A final beta version is expected around the end of the year with the official version slated for release sometime next year. *SVT, LG*

WINDOWS USERS GROUP SERVES EDA COMMUNITY

TechWin EDA Users Group for Windows, a non-profit organization in Los Gatos, Calif., aims to provide a forum for engineers, tool vendors, silicon vendors, and other advocates interested in the issues surrounding Windows-based electronic design automation (EDA). The group held a successful kickoff meeting in June at the Design Automation Conference in San Diego. TechWin will provide education through seminars, workshops, tutorials, and conferences around the world. It also will have support services via on-line communications, such as electronic bulletin boards. There will be an introductory cost to individuals of \$50 a year to join the users group. Full company memberships will be \$500 to \$4000 per year. For more information about TechWin and membership in the EDA Users Group for Windows, call Stan Baker or Deborah Wallace at (408) 356-5119, or E-mail Stan Baker at stanbaker@aol.com or over Compuserve at 73230,1230. *LM*

EDA VENDOR RECEIVES CFI CERTIFICATION

Viewlogic Systems Inc., Marlboro, Mass., was the first EDA vendor to receive Data Representation Procedural Interface (DRPI) certification from the CAD Framework Initiative (CFI), Austin, Texas. This certification is a result of the first formal compliance testing ever performed by CFI. Viewlogic's ViewDRPI was tested extensively to ensure its compliance with release 1.3 of the CFI DRPI specifications. Compliance with this specification takes one step toward EDA-tool interoperability. ViewDRPI provides a CFI-certified procedural interface to connectivity (net-list) design data. In other words, it allows applications to programmatically and interactively create, modify,

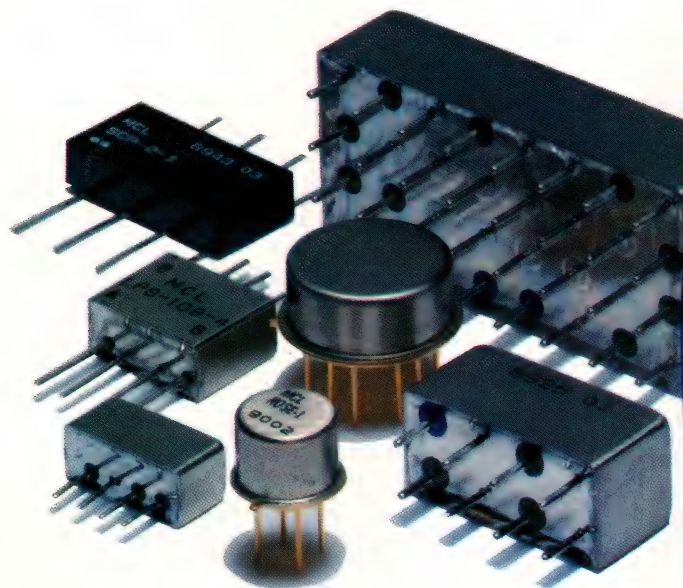
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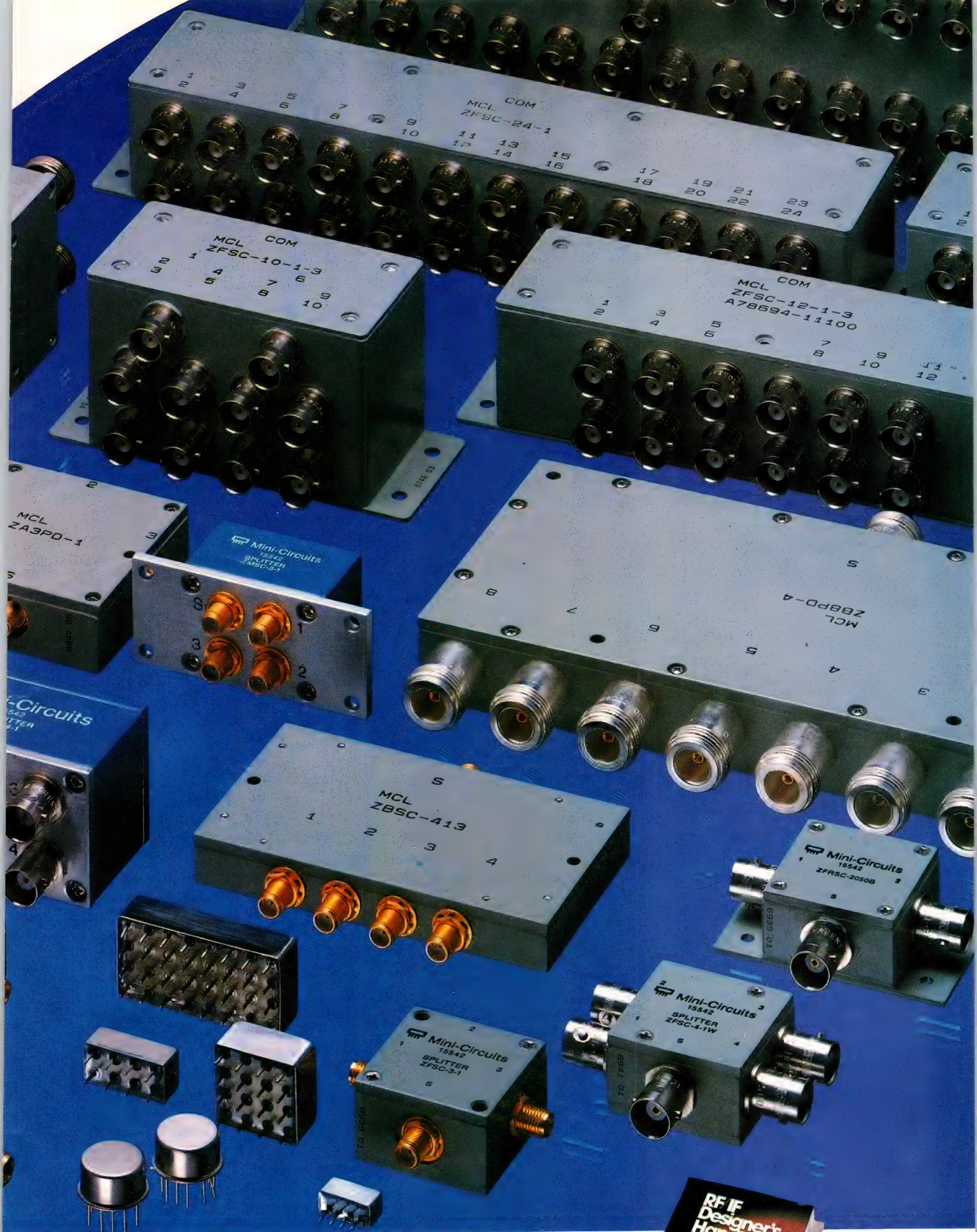


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and access connectivity data using a standard procedural interface. The scope of the DRPI is defined by the hierarchical, electrical connectivity information needed for net listers, logic simulators, timing analyzers, synthesis tools, layout tools, and flatteners. This is the first CFI standard to have a certification test suite. Call Viewlogic at (508) 480-0881. *LM*

EDIF PCB STANDARD WILL DEBUT THIS FALL

The Electronic Industries Association (EIA) Washington, D.C., will release the Electronic Design Interchange Format (EDIF) for pc boards this November. The EDIF PCB information model contains 155 entities that are categorized into 14 sections, including material, geometry, package library, and footprint mapping. Many high-level pc-board constructs, as well as artwork features, will be represented in the new standard. A key component of EDIF PCB is the Design Rule feature, which helps represent simple layout features, complex sub-layouts, pad stack usages, physical nets, sub-nets, layout text, power-plane templates, and probe-point references. Another key section, Assembled Board, will address component net-list definition, component placement, route and wire-bond assembled physical nets, association between components and their footprints, and function-allocation information. EDIF PCB with multichip-module constructs and complex design rules is due out at a later date, and will represent an entirely new direction for the standard. Copies of the specification and licensing agreement can be obtained from the EIA's Patti Rusher at (703) 527-7002. *LM*

COMPUTER-AIDED DESIGN PROMOTES RECYCLING

While most computer-aided designers strive for products with lasting durability, Rajit Gadh is setting new design standards in the fine art of falling apart. The professor of mechanical engineering at the University of Wisconsin, Madison, is conducting research in a new branch of computer-aided design known as "design for disassembly." The end goal of the process is creating products that could eventually be broken down into their component parts—as efficiently as they were put together. Design for disassembly has the potential to turn junkyard-bound products, such as automobile engines and home appliances, into raw grist for the recycling industry. Gadh's research currently involves creating three-dimensional models of complex geometric shapes, all interconnected like a jigsaw puzzle. From thousands of these models, Gadh and his collaborators are looking for geometric shapes that lend themselves to disassembly. Those geometric models could provide the blueprint for a new generation of products that could be disassembled inexpensively and efficiently, making them cost-effective to recycle for the first time.

"The issue is when you are designing the product, design it so you can get its basic components back, its basic chemicals or materials," says Gadh. "Instead of first generating the garbage and having to clean the garbage up, you don't create garbage in the first place."

One of the first motivations for considering disassembly in design, Gadh said, is simply to make parts easier to service, rather than having to destroy some parts to replace others. But a second issue, which is growing in importance, is design for the environment. "This is something the world is going to have to come to grips with," he says. "One cannot continue to produce this huge volume of physical goods and just throw them in the trash."

A recent huge step toward environmentally friendly manufacturing came from Germany, which passed a law this year requiring all German-built automobiles to be recycled by the manufacturer. As it stands in America, cost is the key roadblock to broadening recycling efforts to include products such as appliances, cars, and even computers. *CM*

FLYWHEEL BATTERIES TO FIX ELECTRICAL SURGES

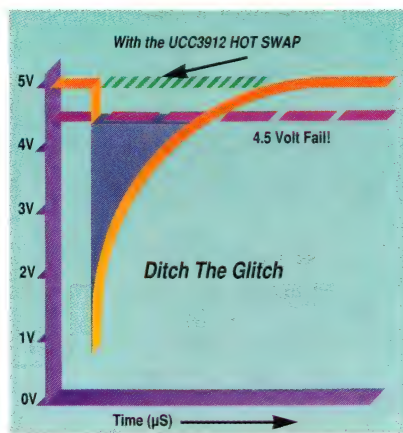
Brief interruptions of electricity create problems for facilities using crucial electronic control and process equipment managed by sensitive computer chips. Consequently, three companies have worked to develop flywheel batteries: Trinity Flywheel Batteries, San Francisco, Calif.; Westinghouse Electric Corp., Orlando, Fla.; and Lawrence Livermore Labs, Livermore, Calif. Designed to smooth out the flow of electricity for factories, computer centers, and other facilities, the batteries consist of four key parts: a motor generator, magnetic bearings, a contaminant system, and a high-strength composite rotor. The electromechanical device converts electrical energy into kinetic energy, which can be stored for later use. As the rotor or wheel spins faster, more energy is stored. Energy can be withdrawn by slowing the rotor's motion. As part of this \$5 million effort, researchers will begin building several prototype batteries for testing, and for evaluation of the battery's contaminant system. They hope the devices will offer higher efficiencies and environmental advantages over conventional electrochemical batteries, as well as lower installation and maintenance costs. The flywheel battery may be available from Westinghouse next year. Contact Steve Wampler of Lawrence Livermore Labs at (510) 423-3107. *CA*

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PRECISION IC-LITHOGRAPHY MEASUREMENT SCHEME TRIMS ERRORS TO LESS THAN 10 NM

The age of deep-sub-micron feature sizes brings with it many challenges, some of which can be likened to the story of the cat chasing its own tail. As the feature sizes shrink further, lithographic tools are needed to create those smaller features. But so are better measurement tools to ensure that those smaller features are properly created. And the more exact the tools are, the finer the features. That, in turn, means even more precise tools will be needed.

Thus, engineers are faced with a daunting challenge: How to provide accurate and consistent tools that can measure the ultra-small mask dimensions at production-line throughputs. The answer lies in a combination of new technology and taking care of all the minute details, according to engineers at Nikon Precision Inc., Belmont, Calif. Close attention to environmental controls, an improved laser interferometer, special construction materials, and a new automated handler were combined to yield a system that measures 0.25- μm feature sizes and can deliver repeatable measurements while keeping error sources to less than 10 nm.

With dwindling on-chip feature sizes, such small error budgets are mandatory. For instance, in 1991, overlays in dynamic-RAM production lines required tolerances of about 0.175 μm , while logic overlays needed about 0.24- μm tolerances and X-Y positioning needed a repeatability of 0.015 μm (see the graph).

Tolerable repeatability also must drop as feature sizes shrink. However, most

of the error sources from the measuring systems were already removed, and attention to the minutiae will be the only way to achieve the desired tolerances. This is particularly important as production systems gear up to manufacture 64- and 256-Mbit DRAMs and even denser memories by the turn of the century.

The resulting accuracy of the system is about two to three times more precise than any other existing production test system, and thus can deliver a much better analysis of patterns it measures. By delivering more accurate results, masks rejected by less-accurate systems due to borderline tolerances that couldn't be evaluated by the less-accurate tools might make it past the more accurate inspection of the XY-5i inspection system. That, in turn, would lower the average mask manufacturing

cost because less masks would be discarded.

Any system that must measure dimensions as small as 10 nm, must, of course, have an internal accuracy close to an order of magnitude better. Consequently, to achieve a pattern-coordinate measurement repeatability of 10 nm, Nikon engineers began by eliminating potential error sources through various methods. For example, liquid cooling was added to the lead screws that move the stage in the measuring chamber. In addition, the air conditioning and air flow were modified to remove all potential heat sources from the measurement chamber that could cause minute dimensional changes.

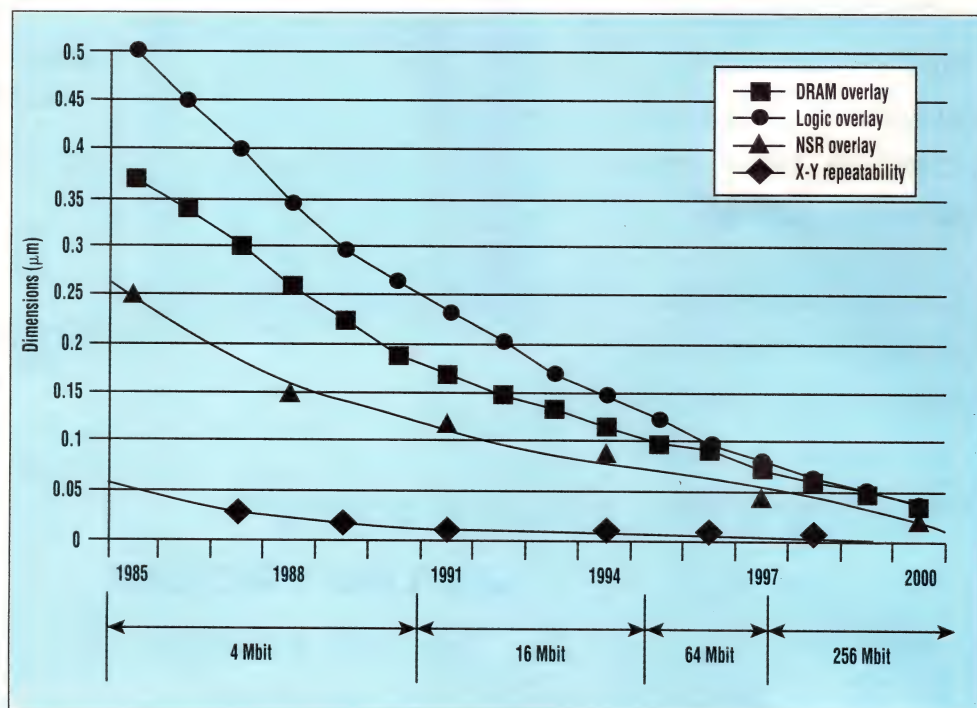
Next, Nikon's designers added a wavelength-tracking system to the laser interferometer, moving from a "weather station" equation to a physical measurement system with a $\lambda/256$

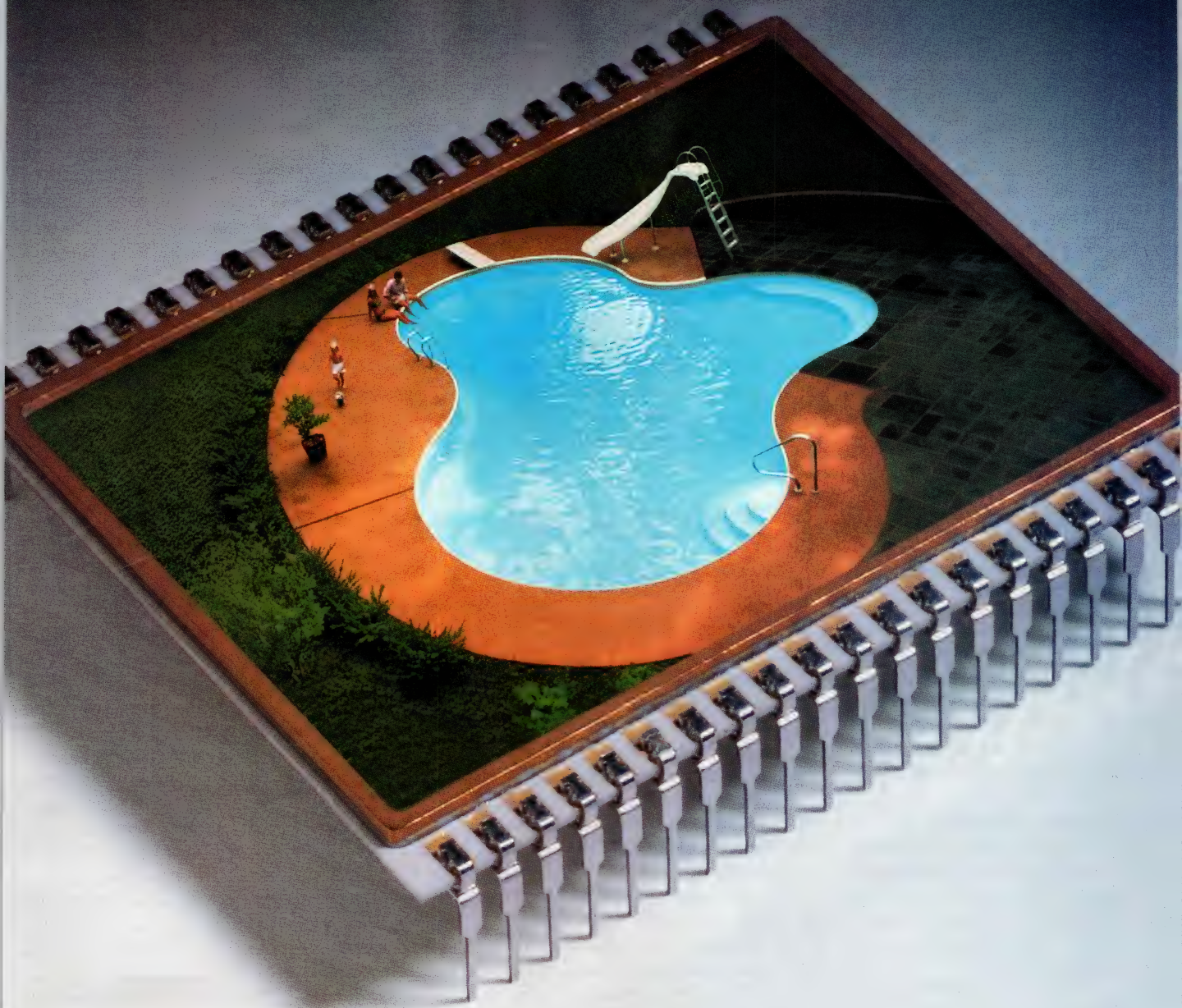
resolution that's more accurate and accounts for atmospheric variations. The higher division ratio improves the laser pulse count (double or more that of previous systems), increasing the resolution and enabling the system to provide finer positioning control.

Large masks typically flex just because of gravity, and even that flexure must be accounted for to perform precision measurements. To do that, a special automatic loading and holding mechanism was developed to hold up to seven 5-, 6- or 7-in. masks without a vacuum.

The three-point support system, which was modeled for each type of substrate, automatically compensates for each substrate size. The automatic aspect of the system also allows the environmental controls to be much tighter, thus further improving the measurement accuracy.

The stage itself also is a source for errors, and not just from its physical movement—temperature causes





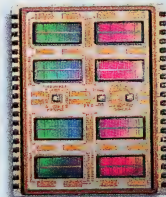
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the stage itself to expand or contract. Thus, Nikon's designers changed the stage material to a special ceramic, which has a very low expansion coefficient.

With all of the performance improvements, the XY-5i system can replace either of Nikon's previous machines, the 2i or 3i, and delivers a measurement accuracy four times better than an alignment tool (alignments are typically done to within 30 to 40 nm), so the XY-5i yields an accuracy of 10 nm. (You may

wonder why there's no 4i. It was skipped over because of superstition. In Japanese, the number 4 when spoken is pronounced like the English word "she,"—in Japanese, it's "shi"—which also is the sound for the word "death". It's for that reason that you won't find anything sold in Japan in sets of four.) For instance, the older XY-2i handled measurements of 150 nm while the XY-5i readily handles 50-nm features with its coordinate-measurement repeatability of 10 nm. Such

repeatability holds for a 3- σ long- and short-term repeatability. This kind of accuracy will be key when measuring critical features on phase-shift masks, X-ray masks, wafers, standard reticles, and other fine-lined objects.

Once measurements are taken, the VAX workstation used as the XY-5i interface can output the data and send it over a network (Ethernet with DECnet or TCP/IP protocols) or compile statistics. The workstation interface gives users

both fast processing and a large storage capacity. As a result, they can collect statistics and perform on-line statistical control to catch defective tools early and minimize lost production.

The ultimate in precision measurement is coupled with a pretty steep price tag as well—system prices will range from \$1.6 to about \$2 million, depending on options.

For more information, contact Dave Kettering at (415) 508-4674.

DAVE BURSKEY

GAS-PHASE AUTO SENSORS ALLOW REAL-TIME MONITORING AND ANALYSIS

Tightening governmental regulations on allowable car emissions has intensified the search for more effective, low-cost methods of monitoring such emissions. As part of a five-year project, scientists at Lawrence Livermore National Laboratory, Livermore, Calif., are investigating various electrochemical sensors to accurately detect and monitor, in real time, the oxygen concentration in a car's exhaust system.

Electrochemical sensors are known for their high sensitivity, small size, low cost, versatility, and capability of standalone operation. Although the potentiometric sensor often is used in industry to monitor gaseous species like oxygen, its sensitivity can't detect changes in oxygen levels in the lean-burn regime. Because future automobiles will operate in this regime, that option won't suffice.

According to Lawrence Livermore scientists, a better solution may be an advanced solid-state electrochemical sensor that's used potentiometrically or am-

perometrically.

The sensor is made up of either ionic materials or semiconductor oxide materials, and is capable of real-time monitoring and analysis. Such a device, used in the feedback control system of an automobile, could accurately monitor the concentration of oxygen in the exhaust stream.

While semiconductor oxide-based sensors may prove effective for emissions monitoring, the option that holds the greatest promise is the amperometric oxygen sensor. The device, consisting of four layers, is rather simple in de-

sign (*see the figure*).

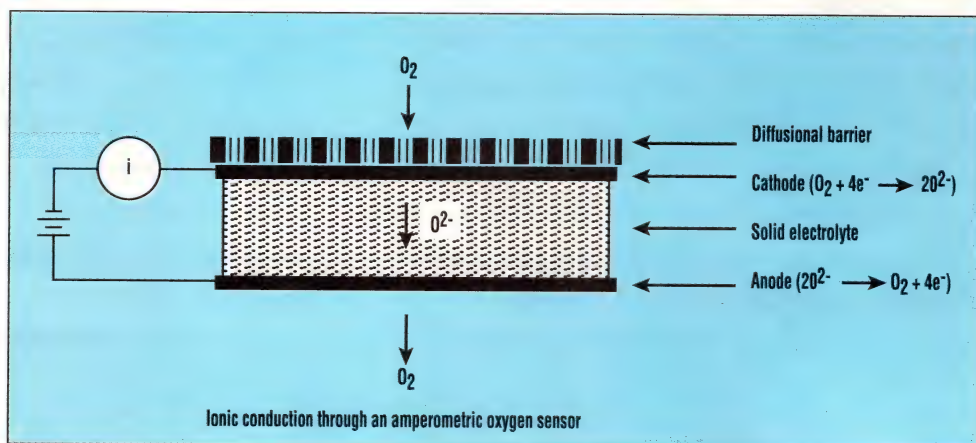
The first layer is a diffusional barrier that only allows passage of the oxygen species being monitored. The second layer, the cathode layer, causes a chemical reaction with the oxygen. It does this by throwing free electrons into the picture, turning O_2 into $2O^{2-}$. The third layer, a solid electrolyte made of CeO_2 , creates an exhaust stream of oxygen. At the last layer, the O^{2-} hits an anode and breaks back down into two forms, O_2 and 4 electrons.

Although the oxygen, in effect, enters and exits the sensor unchanged, the ionic

conduction through the sensor generates a current flow. Because the current is proportional to the oxygen concentration in the exhaust stream, information as to the amount of oxygen present can be ascertained by directly measuring the current.

The amperometric oxygen sensor's development is near the prototyping stage, but the component parts that make up its basic design are still being optimized for performance. For example, while the CeO_2 electrolyte works quite well for low-temperature operations, it's not the answer for operation at other temperature ranges.

Currently, a number of different electrolytes, or



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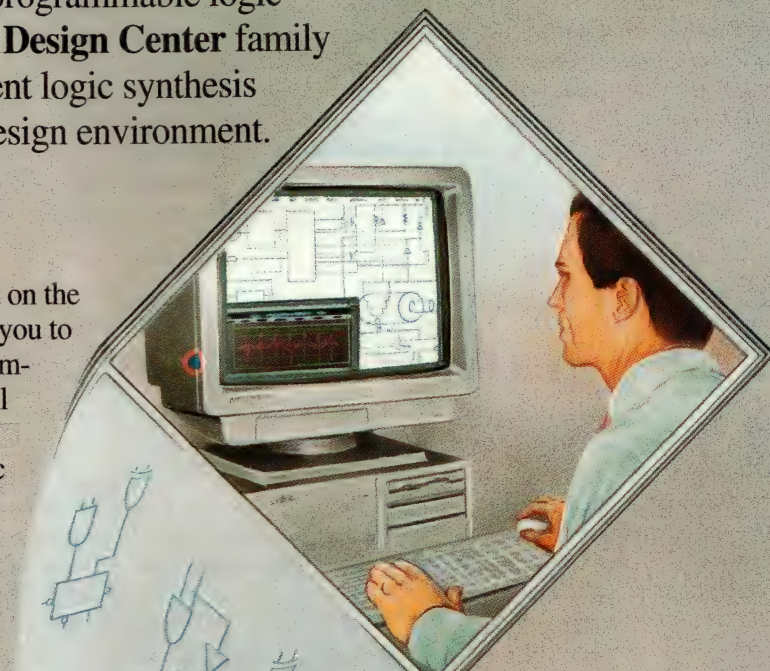
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ionic conductors for the oxygen ion, are under investigation. In addition, to establish a linear response in the appropriate oxygen concentration region, new types of diffusion barriers are being developed that will be applied to the sensor surface. Such barriers include aerogels, xerogels, and perovskites, to name just a few.

Once optimized, the am-

perometric sensor may find a place not just in automotive emissions monitoring. They may also find a home in environmental monitoring and real-time gas specification.

Semiconductor oxide type sensors for various gaseous species, including oxygen, also are being worked on. Fabricated using planar thin-film technology, state-of-the-art mate-

rials deposition, and ion-beam modification, these devices could be microfabricated into an array containing several different sensors on one chip. Such arrays would be ideal for monitoring many different gaseous species, as well as industrial emissions monitoring.

A working prototype of the amperometric sensor is expected by February

1996. The eventual goal is to develop a high-performance, cost-effective means of monitoring and analyzing gaseous species ranging from O_2 , NO_x , CO , H_2 , and SO_2 , to hydrocarbons.

Further technical information may be obtained by contacting Steve Wampler at Lawrence Livermore National Laboratory. Call (510) 423-3107.

CHERYL AJLUNI

POWER-SEMICONDUCTOR PACKAGE DISPLACES TO-247 AND DISSIPATES 4 W

Only a few years ago, the idea of a surface-mount power assembly made most designers feel a little nervous. It wasn't the fact that just that many power semiconductors were unavailable in true SMT versions, which meant relying on risky tactics like bending TO-220 leads into pseudo-SMT shapes. It also involved the prospect of soldering those devices to poor thermal conductor materials like FR-4.

Things began to look up when, in 1991, Motorola Semiconductor Inc., Phoenix, Ariz., introduced its D³PAK, a true surface-mount replacement for the TO-220 that dissipates up to 2.5 W of power. Improved substrate materials such as the intermetallic-substrate (IMS) types have brightened the picture even further. But as power-semiconductor makers like Motorola Semiconductor start to go for larger die sizes with more power-dissipation capability, a true SMT alternative to a larger package such as a TO-247 becomes mandatory. This prompted the development of Motorola Semicon-

ductor's D³PAK, the latest in the DPAK lineage (see the photo).

The D³PAK package is similar in size to the TO-247 package, but can accommodate chip sizes up to 400 by 300 mils (10.2 by 7.6 mm). As a result, designers can use new families of surface-mounted devices, such as power MOSFETs, with lower on-resistances or rectifiers with lower forward-voltage drops.

Designed specifically for SMT applications, the D³PAK offers many other advantages when compared with a lead-formed

TO-247 package. For one thing it's 0.2 in. shorter and has about the same footprint as a 44-pin PLCC package. With a short tab extending beyond its plastic body, the D³PAK's solder fillet can be more readily inspected.

In addition, inspecting the solder joints on a modified TO-247 is virtually impossible. That's because the joint is underneath the package body.

Although the D³PAK is initially targeted for housing power MOSFETs, it also can accommodate devices. These include rectifi-

ers, insulated-gate bipolar transistors (IGBTs), bipolar power transistors, and dual-die configurations such as rectifier/IGBT combinations.

Unlike many SMT packages, the D³PAK lends itself to high-voltage applications because of the wide spacing between its pins. In addition, molded standoffs eliminate the phenomenon of high-voltage creepage and enable the package to be used in applications exceeding 1000 V.

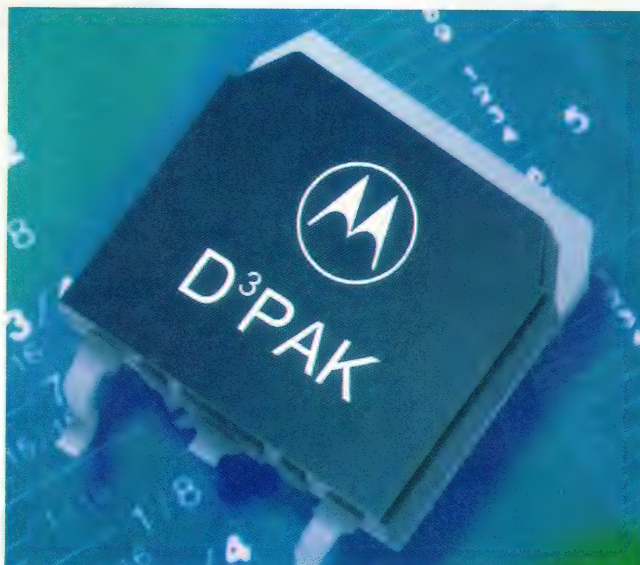
The package is nominally rated for power dissipation of 4 W. But that figure assumes mounting on a conventional FR-4-type pc board.

The 4 W level doubles with use of a heat sink and rises dramatically when the D³PAK is mounted on IMS materials with an aluminum core (it rises to 16.7 W with no heat sink is used and to 27.2 W when a heat sink is used).

Higher levels of power dissipation can be achieved on FR-4 materials, however, by increasing both the copper area of the drain pad and the thickness/weight of the copper located on the pc board.

For more information, contact Motorola Semiconductor's Scott Delaney at (602) 244-3071.

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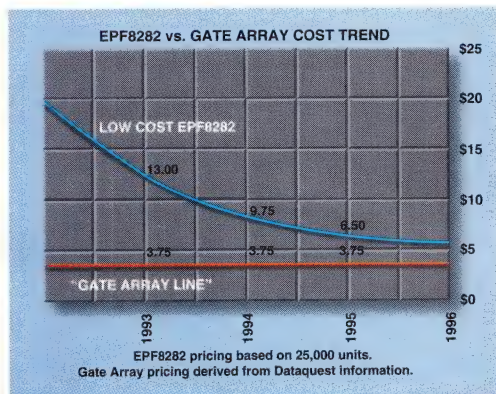
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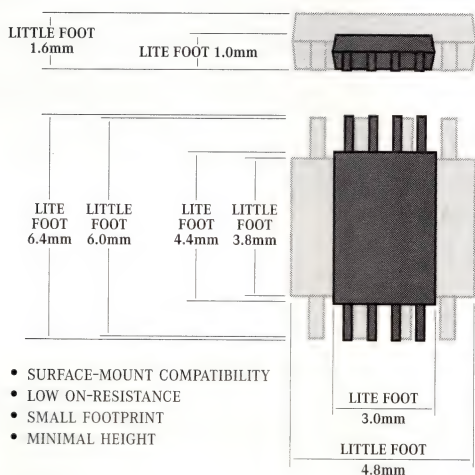
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Si6433DQ	Single P-Ch	-12	75	3.5
Si6447DQ	Single P-Ch	-20	100	3.0
Si6953DQ	Dual P-Ch	-20	200	1.7
Si6542DQ	Complementary N-Ch P-Ch	20 -20	100 200	2.5 1.7

* On-Resistance shown at $V_{GS} = 10$ V, except Si6433DQ shown at $V_{GS} = 4.5$ V

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INNOVATIVE "THUNDERLAN" TECHNOLOGY MAY END HIGH-SPEED ETHERNET STANDARDS WARS

Relief from the war between local-area networks (LANs) is in sight, thanks to a new technology that's culminated from a partnership between Texas Instruments, Dallas, Texas, and Compaq Computer, Houston, Texas. Introduced with the dramatic moniker of "ThunderLAN," the new technology provides LAN users with a bridge between existing 10Base-T and the battling 100-Mbit/s Ethernet technologies (see the figure).

The balkanization of the high-speed Ethernet market began earlier this year when the IEEE Standards Committee announced that rather than choose between the two competing standards—"100 VG-AnyLAN and 100Base-T" for the proposed 100-Mbit/s data rate, it would formally adopt both and "let the market decide". This non-decision has left both LAN equipment manufacturers as well as LAN managers in a difficult position: They have to either risk picking a technology that might quickly become a pariah, or to allow their bandwidth-starved users to continue to suffer with existing 10-Mbit/s networks.

Compaq, a leading computer and server manufacturer, realized that its products would have to interoperate with both of the new LAN standards, so it combined forces with long-time partner TI to solve the puzzle of the divergent technologies. Rather than take a quick-fix approach, TI and Compaq developed a comprehensive solution that would allow users to keep as much as possible of their ex-

isting hardware, software, and wiring as they upgraded to the higher data rates.

Another key goal of the development project was to produce an open standard that could work with nearly any network operating system or physical media. In addition, it would eventually be able to incorporate new transmission technologies, such as asynchronous-transfer-mode (ATM) communications, as a smooth incremental upgrade.

Creating a seamless, system-independent communication technology involved several major tasks. First, a transmission technology adaptable to any one of several protocols and physical layers had to be developed. Next, it was essential to

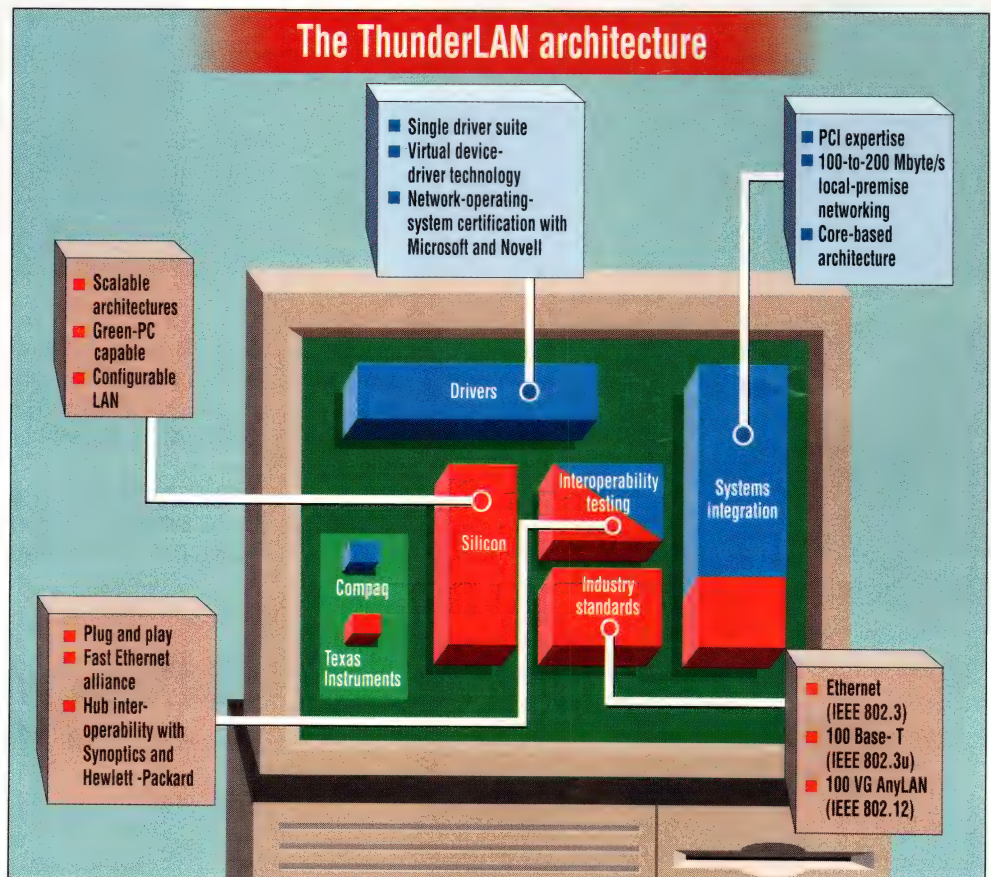
produce a single suite of device driver software that could communicate with the silicon through any major network operating system. Finally, the new technology had to be structured to operate with both high-speed LAN protocols and maintain compatibility with existing 10-Mbit/s systems.

The silicon development fell to TI while Compaq handled the software drivers. Both companies divided the task of assuring that ThunderLAN would interoperate with the three Ethernet standards and their associated hub hardware. To ensure complete compatibility, both companies worked in concert with the Fast Ethernet Alliance, Hewlett-Packard, and Synoptics as well as the In-

teroperability Testing Laboratory at the University of New Hampshire in Durham.

With much of the work already complete, ThunderLAN is gearing up for its launch. TI announced that the first ThunderLAN silicon will be available in the first half of 1995. The initial offering will be a PCI bus interface that can operate on a network using either 10Base-T, 100Base-T, or the 100VG AnyLAN protocols. The technology packs the additional bonus of supporting full-duplex operation for both 10Base- and 100Base-T LANs for a system bandwidth of up to 200 Mbits/s.

The key to ThunderLAN's flexibility lies in its media-independent interface: A small analog personality circuit bridges the standard logic levels of ThunderLAN and the sig-



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nal-modulation scheme used by a particular physical (PHY) layer protocol. On a network interface card, this will most likely take the form of a plug-in module or a daughterboard.

In addition to providing the signal conditioning, these interface circuits will have signal lines that pass their configuration status through the media-access layer (MAC) up to the network operating system, ultimately determining which protocol is being used. This information then will be used by the operating system to select the proper software driver modules and automatically configure itself.

This means that a LAN manager using 10Base-T for most of the network, a few 100VG lines for special applications, and a hub with 100Base-T for tying together high-end workstations need only stock a single type of adapter card for both networks and simply add the appropriate PHY layer module to characterize them.

The chip's front-end will have the necessary circuitry to directly interface to the 10Base-T PHY layer. A standard media-independent interface circuit can be added that handles most physical media interfaces for 100-Mbit/s Ethernet, including TX, T4, UTP, and VG-STP.

Driver software will initially be offered to support most popular operating systems, such as NetWare 3/4, Windows NT, OS2, and SCO UNIX. Others may be forthcoming, subject to demand. These drivers will take up little if any additional memory than conventional software modules, because ThunderLAN's software engineers mini-

mized the amount of PHY-layer-dependent code that was required. While not immediately supported, both TI and Compaq assert that ThunderLAN technology can be easily updated to handle ATM transmissions by adding the proper PHY interface and driver software.

Although the first silicon will be designed for direct interface to the PCI bus, several "bridge" chips will be offered to adapt it to other bus schemes, such as EISA. The bus-oriented interface makes it an ideal candidate for use on motherboards to provide a cost-effective means of manufacturing "LAN-ready" machines. Considering Compaq's involvement in the

technology, it wouldn't be surprising to see several products sporting built-in dual-LAN compatibility before mid-1995.

As a network-systems design house, Compaq took special effort to optimize the driver software. The software group huddled with its own computer systems engineers as well as the major network-operating-system vendors and TI to ensure that the drivers worked with all system elements to coax out every possible bit of speed and efficiency.

Although no firm commitments have been made, TI representatives anticipate that a ThunderLAN adapter card will cost no more than a conventional

10/100-Mbit board which handles a single high-speed Ethernet format, about 1.5 times the price of a low-speed, 10-Mbit/s card. By using this unifying technology, manufacturers and users will be able to avoid the pitfalls of choosing the wrong technology. Network managers also will benefit by being able to upgrade their networks incrementally.

For further information on ThunderLAN technology and its applications, contact the Literature Response Center, Texas Instruments Inc., Semiconductor Group, SC-94084, P.O. Box 172228, Denver, CO, 800217; (800) 477-8924, ext. 4500.

LEE GOLDBERG

COMPRESSION TECHNIQUE INCREASES CD-ROM STORAGE

A novel data-compression technique has led to a new storage technology that significantly increases the storage capacity of standard CD-ROMs. The new technology, called capaCD, allows CD-ROMs to boost their capacities from 1.5 to 10 times (a 3X improvement is typical). The technique, developed by EWB and Associates, Carlsbad, Calif., creates a layer of storage in the CD-ROM. This new "virtual medium layer" is where the additional data is stored.

To the file system, the layer looks like a very large physical layer. Because this layer works independently of the file system, capaCD is compatible with standard CD-ROM file systems, and also with future standards and proprietary file architectures.

The compression technique is lossless, meaning

that no data corruption can occur. In addition, all data returns to its original state after decompression.

No special hardware or software is needed to access the data. Each capaCD-enhanced disk is fully compatible with standard CD-ROM drives and driver software.

The disk itself contains all of the device-driver and support files needed to access the data. When used for the first time, the user simply runs an installation program directly from the CD-ROM. Unlike other compression techniques, capaCD doesn't create an additional drive letter. CD-ROMs possessing the capaCD enhancement can be used interchangeably with disks that don't have capaCD, even after the installation phase.

In capaCD, a data-compression engine called Mul-

tipress combines a number of discrete compression technologies, each optimized for a different data type, into one unified compression engine. Multipress automatically invokes the best data-compression type for each individual piece of data, resulting in the highest possible compression ratio. Multipress also has an interface that can add third-party compression technologies to capaCD, enabling developers to improve storage capacity.

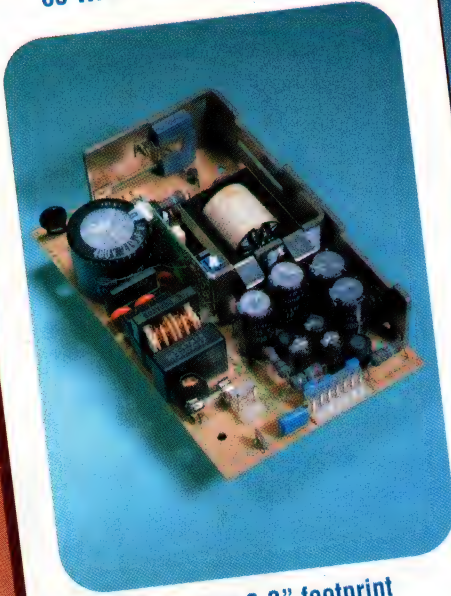
The capaCD technology is available for royalty licensing. The licensing fee depends on the number of CD-ROMs involved. For example, the fee is \$2500 for a minimum quantity of 2000 CD-ROMs, rising to \$35,000 for 50,000 CD-ROMs, and \$175,000 for 500,000 CD-ROMs.

For more information on the capaCD data-compression technology, call EWB & Associates at (619) 930-0440.

RICHARD NASS

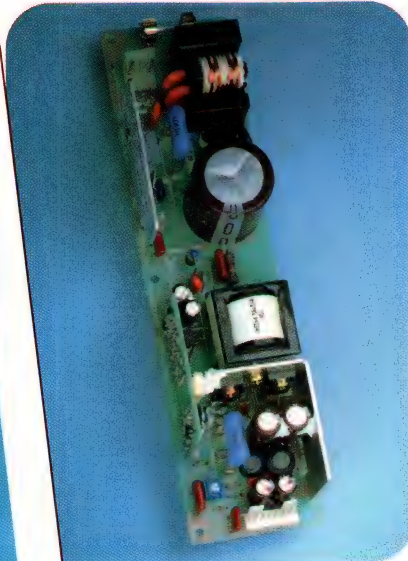
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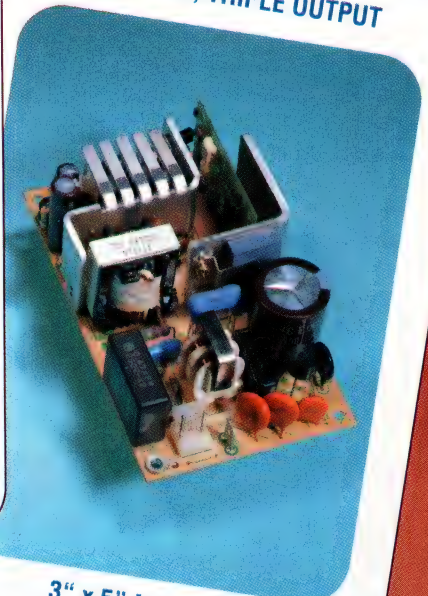
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SPECIFICATION PROPOSED TO PUT PCI ON PASSIVE BACKPLANES

PCI is beginning to break away from the pack and emerge as the leading mezzanine architecture on non-PC platforms. For instance, there's a standard on the drawing board for both the VMEbus and Futurebus+ backplanes. Now another PCI-based specification—the PCI-ISA card-edge connector for single-board computers—is in the works.

This new specification has been proposed by a technical and marketing consortium, the PCI Industrial Computer Manufacturers Group (PICMG). PICMG is made up of a group of manufacturers organized to develop the

standard. The group currently consists of four companies. They include I-Bus PC Technologies, San Diego, Calif.; Teknor Microsystems, Boise Briand, Quebec, Canada; Texas Microsystems, Houston, Texas; and Trenton Terminals, Duluth, Ga. The quartet of charter companies is seeking new members from other manufacturers of industrial CPUs, backplanes and chassis.

The existing PCI standard, originally developed by Intel and now in the hands of the PCI Special Interests Group (SIG), includes specifications for motherboard-based PCs. But it doesn't have a standard specifica-

tion for passive-backplane PCs, which are common in many industrial environments.

PICMG's goal is to draft a set of requirements for the industrial PCI passive backplane and work to have these requirements accepted by the PCI SIG, which represents over 225 companies.

The proposed PICMG specification isn't a redesign of the existing PCI standard. Instead, it adapts the PCI electrical signals to the passive-backplane format.

The 32-bit version of the specification will offer support for up to four master PCI slots. That's made pos-

sible because four signals from the 64-bit extension are relocated.

Four 3.3-V power pins were restored to support future 3.3-V systems. In addition, five pins in the 64-bit extension are reserved to support future functions.

For more information on the PICMG or the associated specification, contact any of the charter members: Curt Alexander of I-Bus PC Technologies at (619) 974-8472; Dan Pirro of Teknor Microsystems at (514) 437-5682; John Leonardo of Texas Microsystems at (713) 541-8200; or Roger Hurlbert of Trenton Terminals at (404) 381-6031.

In addition, the PCI SIG can be reached at (800) 433-5177 or (503) 797-4207.

RICHARD NASS

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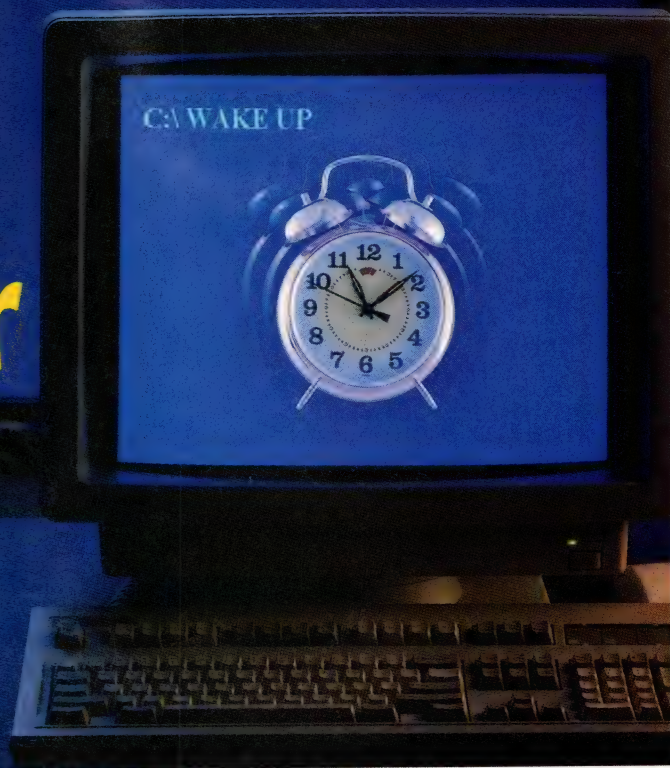
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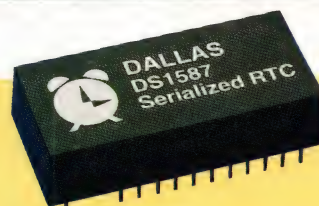
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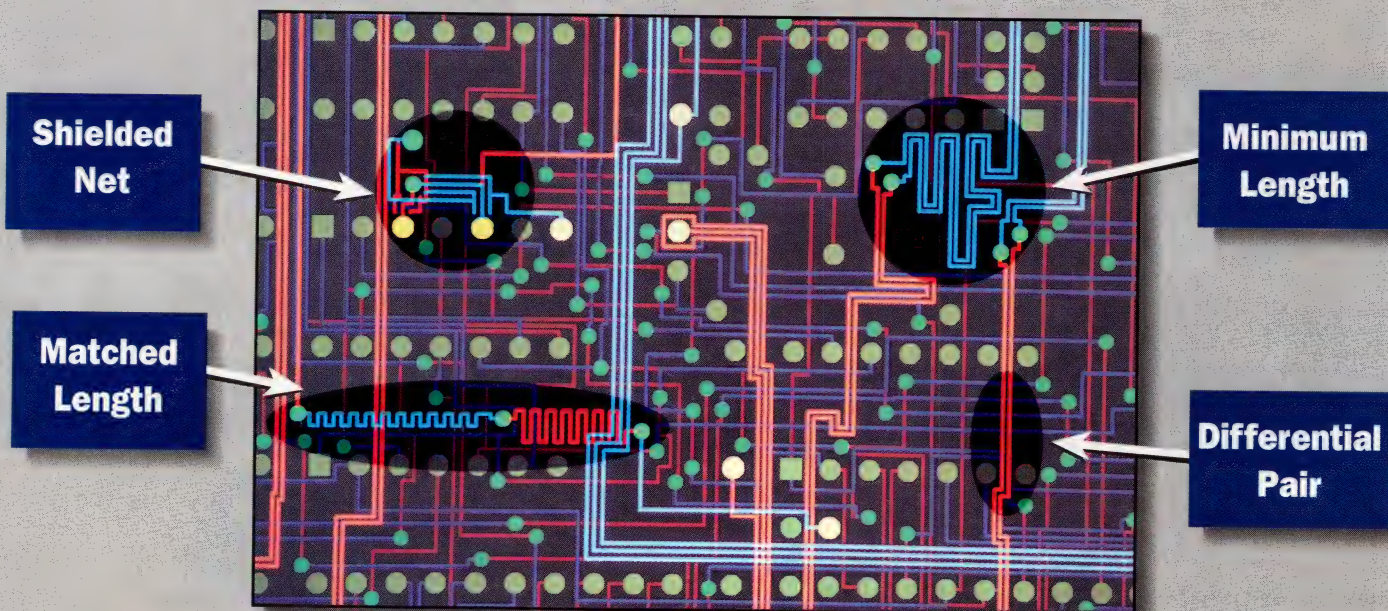
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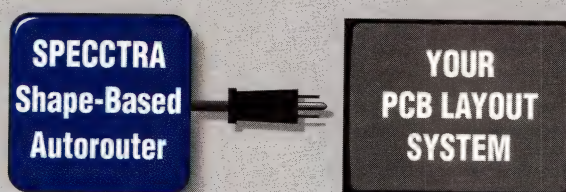
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PCMCIA CARD SLOTS GET POWER-MANAGEMENT IC THAT SETS SEPARATE SUPPLY-RAIL VOLTAGES AND LIMITS CURRENT FOR TWO CARDS.

HOST CPU'S IC MANAGES POWER FOR PCMCIA CARDS

T

FRANK GOODENOUGH

he PCMCIA-card blitz continues unabated, making its way into virtually every application ranging from flash and hard-disk memories to handheld medical equipment and global positioning systems (GPSs). But the onslaught isn't stopping there. Other future homes for the PCMCIA card include data-entry systems as well as data management for automatic test equipment (ATE).

Every PC, instrument, or system, whether portable or not, which takes advantage of the PCMCIA card's versatility for add-on functions must contain circuits that "manage" power for the card. That is, they must provide and control combinations of 3-, 5-, and 12-V power supplies for one or more cards, as requested by each card under a CPU and PCMCIA controller's guidance. Moreover, the power-management function must adhere to PCMCIA standard 2.1. This dynamic standard exists to ensure compatibility between PCMCIA cards and systems and their ability to "plug and play" together.

It takes a dozen low on-resistance semiconductor switches and various other devices to manage the power for a pair of 3-V/5-V PCMCIA cards. And that's regardless of whether the host computer they plug into is a portable system, a desktop system, or an embedded system. With that knowledge and the burgeoning market for the cards, Texas Instruments came up with a complete, dual-slot PCMCIA power-interface switch, the TPS2201IDF (*Fig. 1*). While other similar ICs contain some of the switches and other devices on one chip, the TPS2201IDF is the only one that doesn't need additional off-chip components. Some solutions to PCMCIA power man-



agement require over a dozen extra devices. TI's power-interface switch, on the other hand, not only sets and distributes voltages for two cards, but also protects itself as well as the cards.

In the typical system, the power supply, CPU, PCMCIA controller, and the TPS2201IDF power-interface switch reside in the host computer, while each of the two PCMCIA cards plugs into the host computer

POWER-MANAGEMENT SWITCH FOR PCMCIA CARDS

with a standard 68-pin connector (*Fig. 2*). The PCMCIA controller communicates with the PCMCIA cards via an I/O bus, and with the TPS2201IDF power-interface switch via eight control lines.

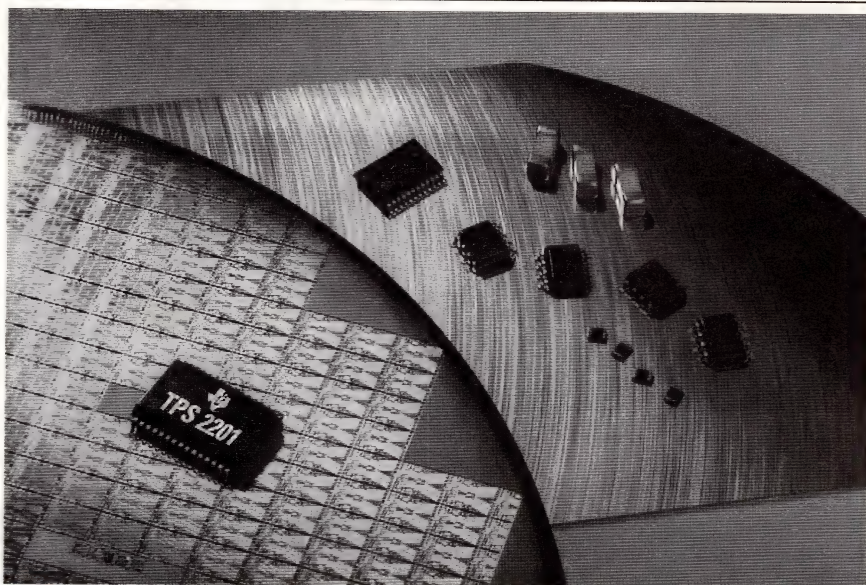
The controller polls each card to determine the voltages it needs and transmits that information to the power-interface switch via the control bus. The switch sets up the voltage distributed to the cards' V_{PP} and V_{CC} pins. To meet the PCMCIA standards, the TPS2201IDF must distribute the following voltages or impedances to the cards' power pins: 0 V, 3 V, 5 V, or a high impedance to the V_{CC} pins, and 0 V, 3 V, 5 V, 12 V, or a high impedance to the V_{PP} pins.

PIN PAIRS

Eight of the standard connector's 68 pins transfer power between the host computer and the PCMCIA card. Two of them carry V_{CC} power, two carry V_{PP} power, and four pins (not shown in *Fig. 2*) handle ground. Multiple pins minimize connector-pin and pc-trace resistances. The cards get their primary power through the V_{CC} pins while the erase and write voltages for flash-memory programming arrive via the V_{PP} pins. Each pin in the 68-pin standard connector is rated at a current of 500 mA. Thus, each pair of pins can physically deliver up to 1 A of current. This assumes identical resistances for each pin and doesn't permit pin failure or resistance change with time or temperature.

Some applications require currents greater than 500 mA from the V_{CC} power supply. For example, a hard-disk drive can demand as much as 750 mA of peak current to create the initial torque to spin up the disk's platter. On the other hand, currents required from the V_{PP} power supply usually top out at the maximum current required to program flash memories, typically less than 120 mA. Of course, this doesn't obviate some oddball application (perhaps a high-speed op amp, an audio amplifier, or some RF task) demanding more than 120 mA of current at 12 V.

As noted earlier, complete implementation of the voltage-setting function takes an even-dozen low-on-resistance (and thus large-area) semiconductor switches (S1 through S12) (*Fig. 3*). However, because all of the



1. THIS 30-PIN SSOP device, designed by Texas Instruments for managing PCMCIA card power, replaces over a dozen discrete components.

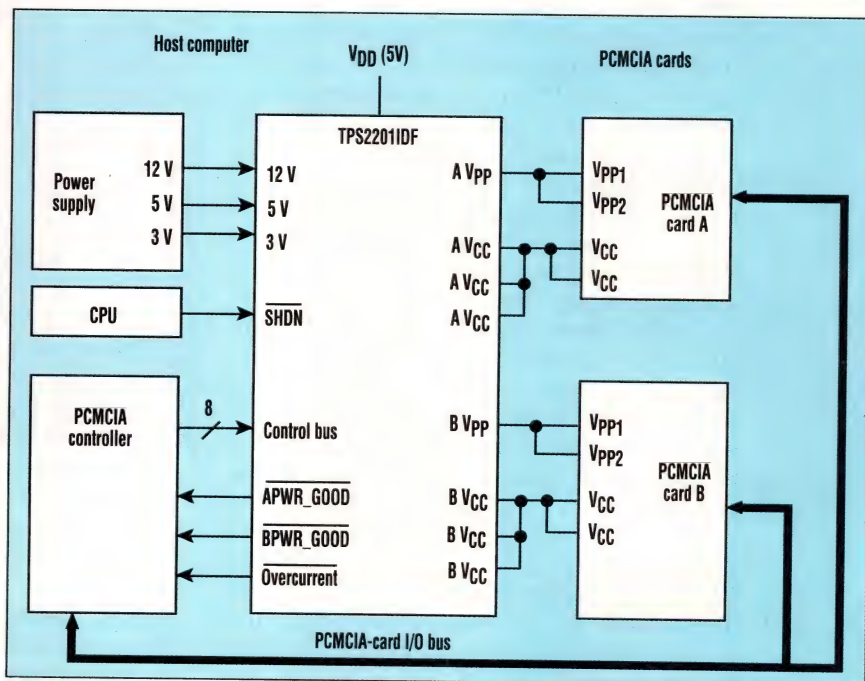
card inputs needn't carry the same supply current, the switches may vary in minimum on-resistance. As a result, they would differ in silicon area.

TI took advantage of these assumptions and squeezed the complete chip into a 30-pin SSOP (*Fig. 1, again*). When switching 5 V to the V_{CC} and V_{PP} pins, maximum on-resistance of the switches is specified as 160 m Ω and 6 Ω , respectively. And, when

switching 3 V to those pins, maximum on-resistance is 300 m Ω and 6 Ω , respectively. If 12 V is switched to the V_{PP} pin, maximum on-resistance is 1 Ω .

Other features of the TPS2201 include:

- A shutdown input ($\overline{\text{SHDN}}$) that when brought to logic low cuts the chip's quiescent current (I_{DD}) from a maximum of only 150 mA to a mere 1 mA while running off a nominal 5-V power-supply rail.



2. THE TPS2201 DUAL-SLOT PCMCIA power-interface IC switch created by TI manages 3-V, 5-V, and 12-V power for PCMCIA cards.

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- Overcurrent limiting.
- An output flag (OC) that goes logic low when an overcurrent condition occurs.

Additional specifications include a "power-ready" flag threshold between 10.72 V and 11.4 V coupled with 50 mV of hysteresis when putting out a nominal 12 V, and maximum leakage current at high-impedance outputs of 10 mA. When operating from a nominal 5-V power-supply rail, the input voltage ranges from 0 to 5.25 V on the power supplies' 3- and 5-V inputs, and 0 to 13.5 V on the 12-V input. The "slowed-down" rise and fall times of the 3- and 5-V outputs run 1.2 and 10 ms, respectively; that of the 12-V out-

put runs 6 and 0.25 ms. Propagation delays to all outputs run 300 ms.

CHANGING STANDARD

The TPS2201IDF's functionality ultimately was driven by the need to conform to the latest issue of the PCMCIA standards. The current trend in the PC market involves a rapid move from 5-V-only to 3-V/5-V systems, and ultimately in a few years to 3-V systems. The purpose of this voltage reduction is to minimize power, optimize board space, and increase logic speed.

The new requirement for 3-V/5-V cards has necessitated the creation of a protocol to transition between two voltages. Cards are initially powered up at 5 V. If 3-V compatibility between the host computer and the card is determined when the CPU reads the "card information structure" (CIS),

the card is then powered up at 3 V. That is, for example, the CPU would tell the TPS2201IDF to put 3 V on its V_{CC} pins.

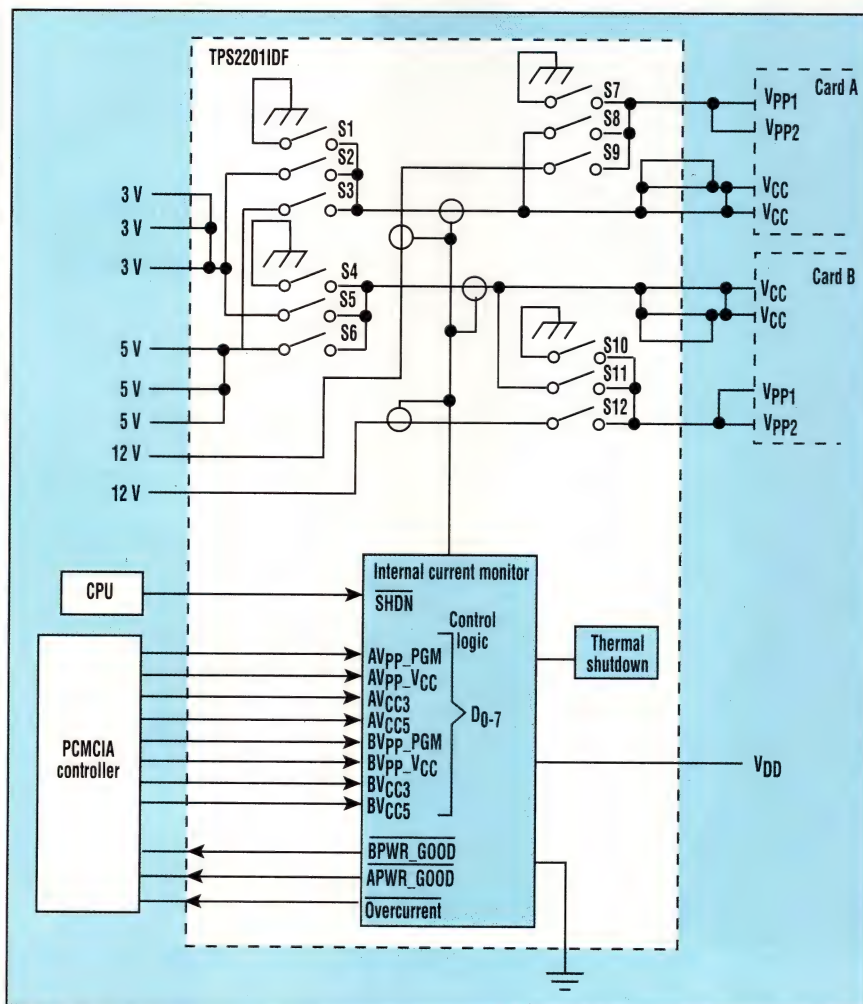
However, the protocol demands that during transitions between 5 V and 3 V, the host computer must first discharge the PCMCIA-card's capacitors to less than 0.8 V before subjecting the card's input circuitry to 3 V. Such a transition through 0.8 V ensures that sensitive 3-V circuitry isn't subjected to residual amounts of 5-V charge left on the card's input filter capacitors. This function provided by the TPS2201IDF essentially acts as a power reset. Other available PCMCIA card power-interface switches provide only a high impedance, which doesn't offer a path to bleed off the 5 V.

A DOZEN SWITCHES

Opening or closing switches S1 through S12 on the TPS2201IDF performs the voltage-rail switching function, delivering whatever voltages the PCMCIA cards call for (Fig. 3, again). The eight lines from the PCMCIA controller select the required switches as defined by the TPS2201IDF's control logic (see the table).

The first column in the table indicates the condition of each switch, depending on the status of the shutdown input. Columns two and three represent the eight control line inputs. Columns four, five, and six indicate the effects of the eight control line inputs on the 12 switches. The last column represents the output voltage delivered by the chip to the PCMCIA-card connector's power-output pins. Using two control lines to set each output voltage permits those outputs to transition between four states. All of the switches that control a single output contain "break-before-make" contacts to prevent erroneous output-voltage transients.

All 12 switches employ n-channel, low-voltage, lateral DMOSFETs. When switching, these FETs need a voltage higher than V_{DD} to turn them on. The TPS2201IDF chip contains its own charge pumps that develop the required gate voltage to turn on each switch. Moreover, these pumps don't require any external capacitors because they're on-chip, and only require the host-computer 12-V supply to be turned on when 12 V is needed



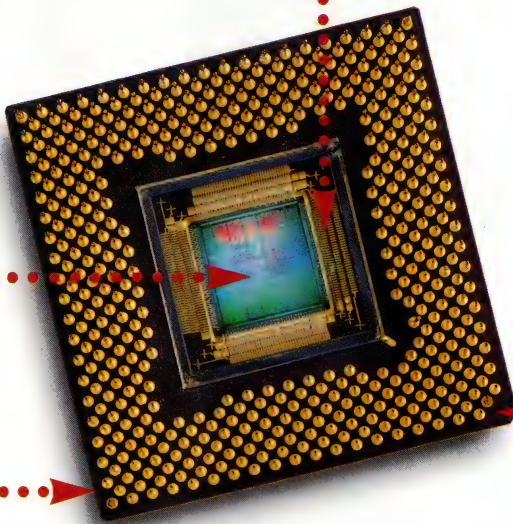
3. A DOZEN DMOSFET SWITCHES within the TPS2201 operate under the aegis of a CPU and a PCMCIA controller. They apply the required mix of 3-V, 5-V, and 12-V power to a pair of PCMCIA cards.

BIG DIE

1.60 inches square, embedded memory, and over 100,000 gates. A very big die.

BIG I/O

504 I/O pads, arranged in two rows around the periphery of the chip.



BIG HEAT

Running at 20 MHz and generating eight watts of power. With this much power, we had to pipeline the heat away from the die.

BIG PACKAGE

The only off-the-shelf package that met all the technical specifications was three to four times too expensive. The solution: a custom ceramic PGA, shown here at actual size.

NO BIG DEAL

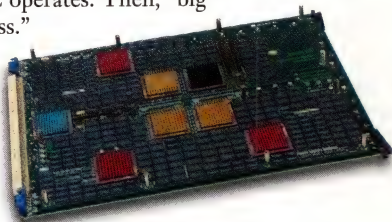
"Big" does **not** have to equate to "big deal." As in problems. As in endless delays. As in unforeseen costs. Not when you have an ASIC vendor that understands the system-level context in which an ASIC operates. Then, "big" can lead to "big success."

That's what IKOS Systems found out recently, when they brought the custom gate array you see above to American Microsystems, Inc.

To create their next-generation hardware accelerator for logic simulation, IKOS needed to embody their evaluation algorithms in four ASIC designs with over 300,000 gates of custom logic in all.

If AMI were the kind of ASIC vendor who thinks their responsibility ends at the netlist, this project could have been a very big deal—and a very big headache—for IKOS Systems.

Instead, AMI worked with IKOS Systems and a qualified package vendor to design a custom ceramic pin grid array that met all of the extensive physical, electrical and thermal constraints represented by a gate array of this complexity.



We thought the IKOS System development was a big challenge, to be sure, and we're glad that for our customer, it was a big success. But, with over a quarter-century of ASIC experience, meeting big challenges and creating big successes for our customers is never a "big deal."

So the next time you're faced with that potentially "big deal" development, come to the ASIC vendor that can help you knock it down to size—AMI.

For a free case study of the IKOS Systems development, jointly authored by AMI and IKOS Systems, or for additional information about AMI's products and capabilities, call 1-800-NEWS-AMI today (1-800-639-7264).

See us at Booth #3253 at Wescon & idea/Microelectronics '94 September 27-29, Anaheim Convention Center, Anaheim, CA.

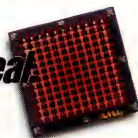
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POWER-MANAGEMENT SWITCH FOR PCMCIA CARDS

TPS2201 CONTROL LOGIC

I ² C 2201 CONTROL LOGIC								
A V _{PP}	Control Lines		Switches			Output voltage to pin		
SHDN	A V _{PP} programming	A V _{PP} , V _{CC}	S7	S8	S9	A V _{PP}		
1	0	0	Closed	Open	Open	0 V		
1	0	1	Open	Closed	Open	V _{CC}		
1	1	0	Open	Open	Closed	V _{PP}		
1	1	1	Open	Open	Open	High Z		
0	X	X	Open	Open	Open	High Z		
V _{PP} for card B								
SHDN	B V _{PP} programming	B V _{PP} , V _{CC}	S10	S11	S12	B V _{PP}		
1	0	0	Closed	Open	Open	0 V		
1	0	1	Open	Closed	Open	V _{CC}		
1	1	0	Open	Open	Closed	V _{PP}		
1	1	1	Open	Open	Open	High Z		
0	X	X	Open	Open	Open	High Z		
V _{CC} for card A								
SHDN	A V _{CC5}	A V _{CC5}	S1	S2	S3	VA V _{CC}		
1	0	0	Closed	Open	Open	0 V		
1	0	1	Open	Open	Closed	3.3 V		
1	1	0	Open	Closed	Open	5 V		
1	1	1	Closed	Open	Open	0 V		
0	X	X	Open	Open	Open	High Z		
V _{CC} for card B								
SHDN	B V _{CC5}	B V _{CC5}	S1	S2	S3	VA V _{CC}		
1	0	0	Closed	Open	Open	0 V		
1	0	1	Open	Open	Closed	3.3 V		
1	1	0	Open	Closed	Open	5 V		
1	1	1	Closed	Open	Open	0 V		
0	X	X	Open	Open	Open	High Z		
Serial-interface register								
D8	D7	D6	D5	D4	D3	D2	D1	D0
SHDN	B V _{CC5}	B V _{CC3}	B V _{PP} V _{CC}	B V _{PP} PGM	A V _{CC5}	A V _{CC3}	A V _{PP} V _{CC}	A V _{PP} PGM

for flash-type memories. This latter feature can increase battery life significantly.

The on-chip charge pumps are designed to provide a slow ramp when switching the V_{CC} line. This feature helps prevent peak supply currents that can pull down the host-computer's power supply during the process of card initialization, which in turn causes indeterminate states in the system logic.

Delivery of power from a host computer to a PCMCIA card requires protection in the form of a fuse or current limiting. In addition, the "portability" of the PCMCIA cards ensures that they will be subjected to significant physical abuse. A card with a short circuit can kill a host-computer's power supply or open a pc-board trace.

In the past, fuses were used for protection because other techniques

added too much resistance in the power-delivery path, causing additional unacceptable voltage drops in these high-current lines. However, relying on fuses can cut system reliability because host computers often must be returned for repair when damaged by a bad card. In addition, a bad card will likely drain a battery in just a few minutes.

Marco Corsi, the designer of the TPS2201IDF, attacked these problems in several ways. The chip monitors the outputs for overcurrent conditions and reports such conditions to the host computer/user. SenseFETs, which employ some of the MOSFET cells that form each DMOSFET switch, monitor the current because other techniques would have added series resistance. Such resistance would otherwise cut power transfer to the load. Each of the power outputs is current-limited for an overcurrent

condition and the condition is reported via the overcurrent flag. This signal can be employed by the controller, or the CPU, to inform the user of the system's status. Finally, if the overcurrent condition persists until the die exceeds its maximum allowable junction temperature, the chip is shutdown until the temperature drops to a safe value. □

PRICE AND AVAILABILITY

The TPS2201IDF dual-slot PCMCIA power-interface switch, in its 30-pin SSOP, is rated for operation over the extended-industrial-temperature range. In quantities of 1000, it goes for \$6.67 each. Texas Instruments Inc., Literature Response Center, SC-94081, P.O. Box 172228, Denver, CO 80217; (800) 477-8924, ext. 4500.

CIRCLE 514

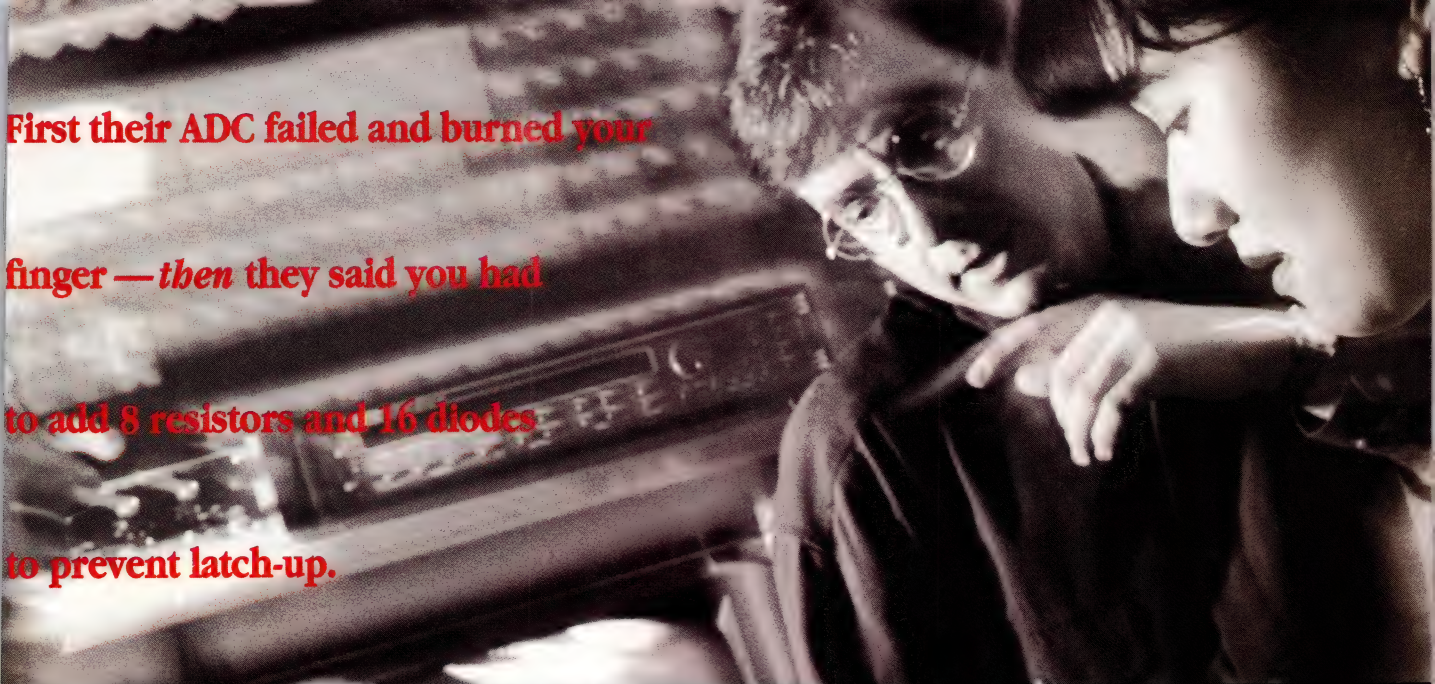
HOW VALUABLE?

HIGHLY
MODERATELY
SLIGHTLY

CIRCLE

534
535
536

First their ADC failed and burned your
finger — then they said you had
to add 8 resistors and 16 diodes
to prevent latch-up.



FINALLY, THERE'S A FAMILY OF 12-BIT ADCs THAT WON'T ACT LIKE THIS IN YOUR SYSTEM.

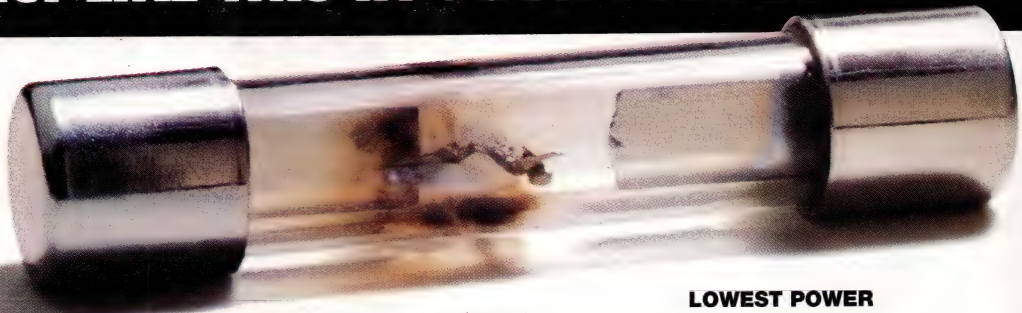
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If an 8-channel ADC with a separate MUXOUT that uses only one eighth of the signal conditioning circuitry sounds good, try our new 12-bit AD7890.

READER SERVICE 137

LOWEST POWER

Coming soon, our newest family member, the AD7892. It's the lowest power ADC available with a 500 kps throughput rate.



SPECIFICATION	AD7890	AD7893	AD7892
Throughput (kps)	100	117	500
Channels	8	1	1
Power Dissipation	30 mW	25 mW	60 mW
Price (1000s)†	\$10.20	\$9.00	\$13.60

Solutions for any ADC problem: 8-channel with separate MUX... smallest 8-pin SOIC package... lowest power 500 kps.

And it offers very flexible interfacing, with both serial and parallel capability.

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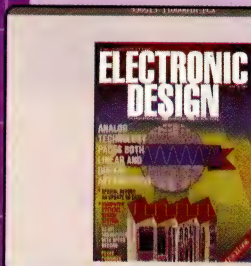
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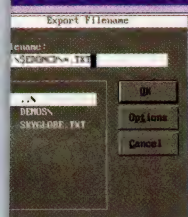
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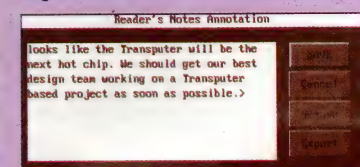
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CLR - *Clear Back Links* - Because every article you move to loads into RAM, this function allows you to clear articles you've finished. This frees up RAM for you to continue.

TOC - *Table of Contents* - Takes you directly to the Volume Table of Contents (the whole year) with special links provided to Issue T.O.C.

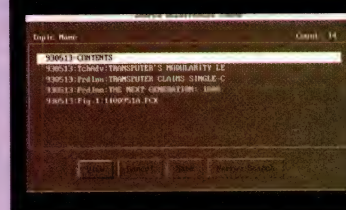
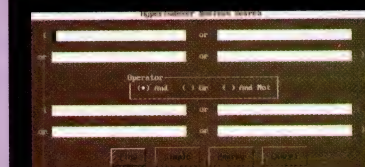
History Function	
Duration	Topic Name
19 Secs.	ELECTRONIC DESIGN ON CD-ROM: CONTENTS
2 Secs.	930513: CONTENTS
26 Secs.	CLR : Clear Backward Links
3 Secs.	930513: CONTENTS
38 Secs.	Navigation Aids Functions
3 Secs.	930513: CONTENTS
17 Secs.	CLR : Clear Backward Links
8 Secs.	ELECTRONIC DESIGN: 1989-1993

REL - *Show-Related Articles* - Calls up a list of, and lets you move to, related topics.

HST - *Show-Related History* - Shows each topic visited during your current session and how long you were there, and then lets you return to previous topics.

SEARCH dialog boxes

Simple search (top), Complex Search (center), and Search occurrences found (bottom).

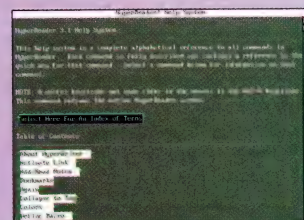


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MINIMUM SYSTEM REQUIREMENTS

- 80386 PC or better
- 1 meg ram
- VGA video card adaptor w/640 x 480 pixel resolution 16 colors.
- MS-DOS Version 3.1 or later

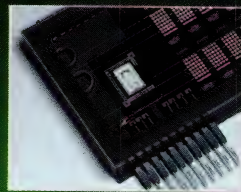
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NEC's Fluorescent Indicator Panels (FIPs) incorporate a light-emitting technology which gives them three key advantages over other displays. FIPs are brighter ($1,000\text{cd/m}^2$) and easier to read from adverse angles or extended distances; they're more compact, and they offer higher reliability.

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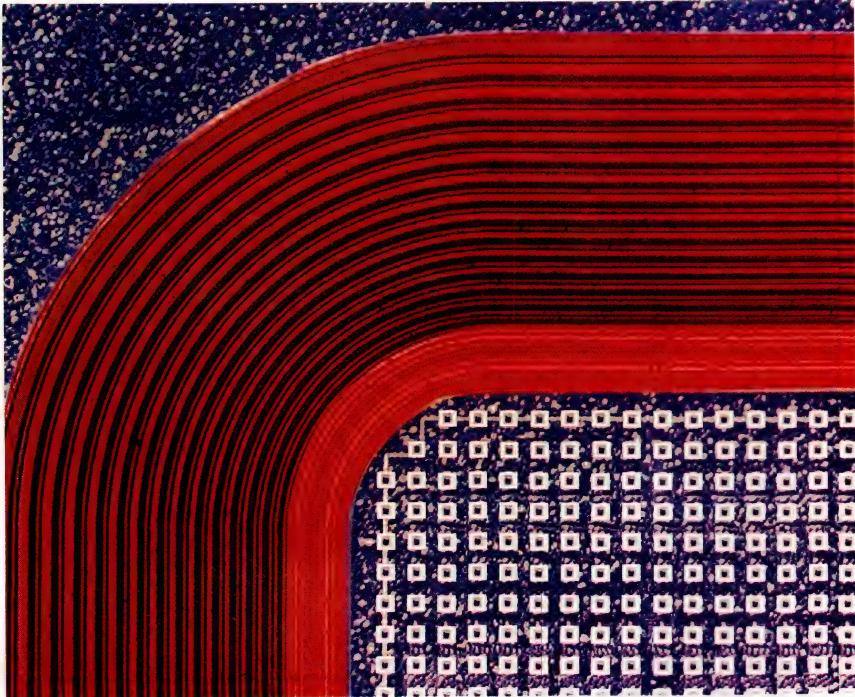


Type	Character/line	Character size H x W (mm)	Dimensions (mm)
FC16X2CA-AB	16 x 2	5.05 x 3.35	34 x 142 x 23
FC20X1RA-AB	20 x 1	5.0 x 3.3	26 x 161 x 23
FC20X1SA-AB	20 x 1	9.0 x 6.3	26.5 x 230 x 23
FC20X2JA-AB	20 x 2	5.05 x 3.35	34 x 161 x 23
FC40X1LA-AB	40 x 1	5.0 x 3.3	26 x 256 x 23
FC40X2EA-AB	40 x 2	5.0 x 3.3	39.5 x 256 x 27

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NEC



COURTESY: MOTOROLA SEMICONDUCTOR

DMOSFETs SWITCH MILLIWATTS TO MEGA WATTS

This report is the first part of a two-part report on low-voltage (below 100 V) cell-based MOSFETs, insulated-gate bipolar transistors (IGBTs), and MOS-controlled thyristors (MCTs). The second part, which covers high-voltage devices, will appear in a future issue.

FRANK GOODENOUGH

VERTICAL FETs
DOMINATE
LOW-VOLTAGE
POWER-
TRANSISTOR
SWITCHES.
AT HIGH
VOLTAGES, THE
IGBT IS
BECOMING THE
CHOICE.

Demands for efficient power control of systems and products continues to fuel the technological advances in cell-based discrete power transistors that dominate low- and high-voltage applications. Such systems include portables like subnotebook PCs and camcorders, as well as power-factor-correcting lamp ballasts and multi-horsepower motor drives. Unlike the discrete small-signal silicon transistor that's gone the way of the germanium transistor into the "sunset industry" brigade, the discrete power transistor is alive and well, particularly for switching tasks. Also, novel devices in different packaging for new applications are arriving daily.

Low-voltage (low drain-source voltage) applications ranging from switching regulators and motor controllers to power management for PCs are dominated by the vertical DMOS power MOSFET. On top of that, power MOSFETs have taken over many high-voltage bipolar ap-

CELL-BASED POWER SWITCHES

plications for new designs. In this venue, the IGBT is starting to challenge the MOSFETs' authority.

One major trend sweeping through the low-voltage realm is the appearance of very low on-resistance FETs with sub-35-V breakdown voltages (see "A sampling of the latest low-voltage MOSFET products," p. 60). They're being driven by their increasing use in management applications for battery powered devices with logic that's 5 V and lower.

These n- and p-channel devices offer a sub-100-m Ω on-resistance ($R_{DS(on)}$). Moreover, some become fully enhanced (turn on hard) with 5 V or even less between the gate and source. In contrast, typical power FETs take 10 V for full enhancement while IGBTs like to see more than 10 V. However, at low voltages, vertical FETs now are facing off with n- and p-channel MOSFETs (giant logic FETs) and even lateral DMOS devices. All varieties of these low-voltage, low- $R_{DS(on)}$ FETs are useful in low-voltage switching regulators. There, they serve as both the power switch and as synchronous rectifiers replacing the usual fast-recovery or

Schottky diode rectifier.

IGBTs are finally infringing on the DMOSFET's territory at high voltages and in applications where their limited speed isn't a handicap. But the high-voltage DMOSFET isn't standing still: high-voltage termination has been improved to increase reliability and electrical ruggedness; work is underway to lower $R_{DS(on)}$ to cut conduction losses; and gate charge is being reduced to lower switching losses. Pure bipolar devices such as transistors and thyristors (SCRs, GTOs, and TRIACs) still compete with the more expensive cell-based FETs and IGBTs, and will continue to compete in the foreseeable future. The MCT is also waiting in the wings to handle high-voltage, high-current switching tasks.

POWER PACKAGES

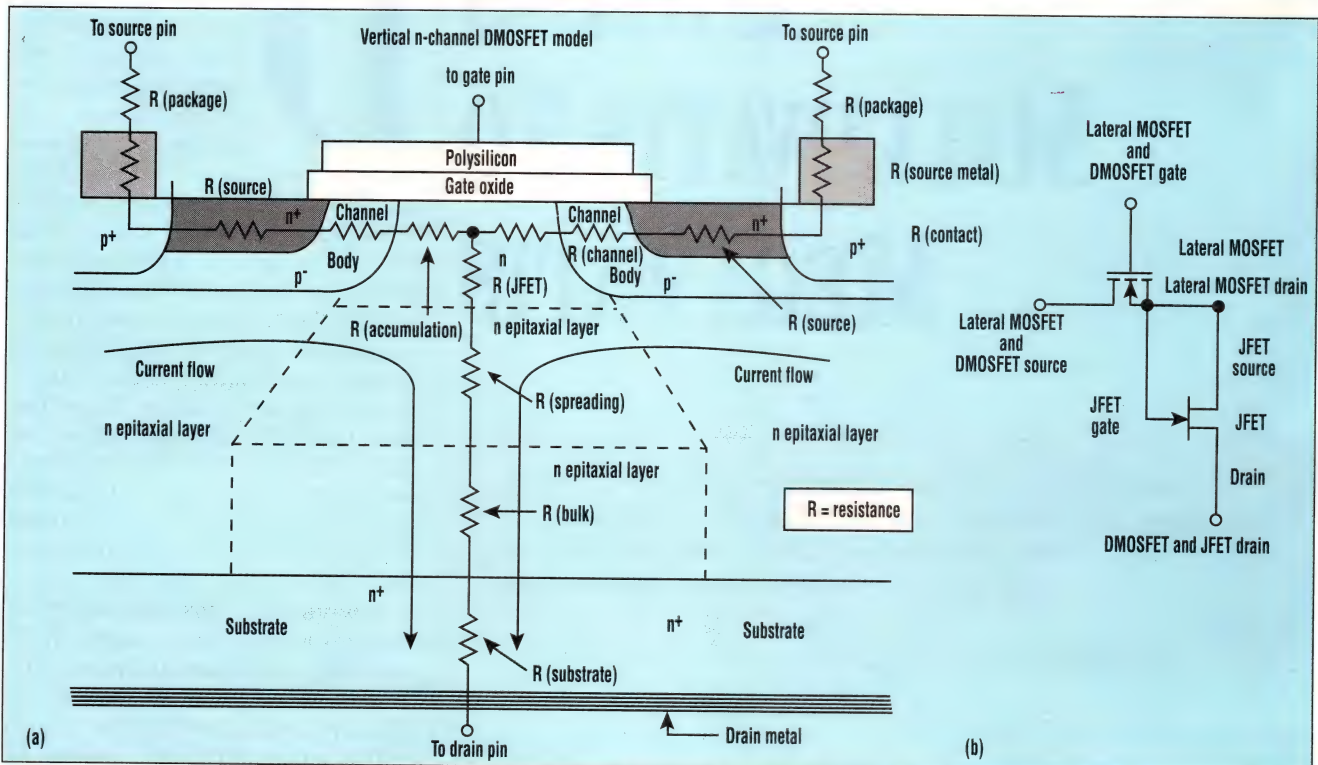
The achievements made in power packages are driven by several factors. For starters, the demand for an ever lower $R_{DS(on)}$ dictates new packaging techniques. For example, when switching a 2.7-V, 1-A power-supply rail, bond wire and lead/pin resistances can overwhelm the $R_{DS(on)}$ of a sub-100-m Ω FET die. The

move to surface-mount packages, along with the desire for tinier package footprints and thinner cross sections (for PCMCIA applications), further exacerbates this problem. Finally, at voltages above a few hundred volts, the creep distance between pins must be considered.

At the low end of the power-MOSFET spectrum, many low-voltage MOSFETs handling over 1 A of current can be found in various versions of the small SOT-23 and 8-lead TSSOPs. At the high-power end, FETs and IGBTs are available in TO-264 and SOT-227 ISOTOP packages. And, sub-100-V FETs in the SOT-227 can handle over 100 A.

Yet despite all of these novel packages, the venerable TO-3, which housed the first germanium power transistors, remains the choice of first and last resort where hermeticity is needed (at least until a successor is developed, none of which are on the horizon). On the other hand, very few new power semiconductors will be available in TO3s.

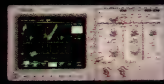
Still, the bipolar power transistor refuses to go away. It offers cost and even functional advantages over the IGBT in a few high-voltage applica-



1. THE ON-RESISTANCE OF VERTICAL DMOSFETs CAN BE MODELED as eight separate resistances (a). In this model, a lateral MOSFET drives a JFET (b).



NEW [TDS 310]
2 Chan/50 MHz



NEW [TDS 410]
2 Chan/150 MHz

the TDS 500 series

Precision, extended
record length and
waveform analysis



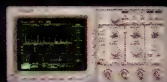
[TDS 544A]
4 Chan/500 MHz



[TDS 644A]
4 Chan/500 MHz

the TDS 300 series

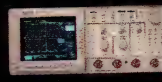
Our most affordable
family of DSOs



[TDS 420]
4 Chan/150 MHz



[TDS 520A]
2 Chan/500 MHz



[TDS 620A]
2 Chan/500 MHz

the TDS 800 series

Highest resolution
and bandwidth



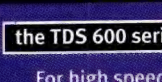
[TDS 320]
2 Chan/100 MHz



[TDS 460]
4 Chan/350 MHz



[TDS 524A]
2 Chan/500 MHz



the TDS 600 series

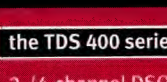
For high speed
digital/analog
applications



NEW [TDS 684A]
4 Chan/1 GHz

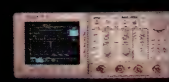


NEW [TDS 350]
2 Chan/200 MHz



the TDS 400 series

2-/4-channel DSOs
for bench and field
applications



[TDS 540A]
4 Chan/500 MHz



[TDS 640A]
4 Chan/500 MHz



[TDS 820]
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CELL-BASED POWER SWITCHES

tions, such as CRT deflection amplifiers. It also offers a cost advantage over MOSFETs in audio amplifiers. Moreover, because it's in high-volume production for numerous power-supply and motor-drive designs, it will remain an economic alternative for the designer who wants to fuss with the complex, power-hungry, drive problems (relative to FETs and IGBTs) of those applications.

HIGH VERSUS LOW

Just as applications for high-voltage devices differ significantly from those for low-voltage devices, so do the processes used to build the ICs. In this report, MOSFETs with breakdown voltages above 100 V are con-

sidered high-voltage devices, while those rated at 60 V and below are considered low voltage. As with any such arbitrary definition describing a fast moving technology, there are no specific rules. Some might say three MOSFET voltage categories exist: 30 V and below, 30 to 200 V/300 V, and above 200 V/300 V. Today, a fourth category could be added—12 V and below. The time may come when we will see power FETs, like logic ICs, rated at 6 V.

As IGBTs gain switching speeds and their forward voltage drops (conduction loss) shrink, the voltage at which they become the switch of choice becomes a similar moving target, falling to lower levels. Original-

ly aimed at applications of 500 V and above, they're now finding homes handling voltages ranging between 200 and 300 V, and they may ultimately find applications at 100 V. Not all suppliers agree that IGBTs can move to applications below 500 V. Likewise, the original maximum practical switching frequency of 20 kHz has risen to over 100 kHz and is still climbing. This year should see 200-kHz IGBTs.

As noted earlier, most power FETs require at least 10 V between gate and source to reach full enhancement. That is, they need at least 10 V to turn on hard enough to achieve minimum specified $R_{DS(on)}$. However, about 10 years ago, Harris

A SAMPLING OF THE LATEST LOW-VOLTAGE MOSFET PRODUCTS

A host of low-voltage MOSFET products have recently burst on the scene. Some of the more notable ones include:

- *The first 60-V TrenchFETs with the lowest $R_{DS(on)}$ in TO-220 and TO-263 (D²) packages.* Siliconix's five vertical DMOSFETs, which use trench gates, are based on a process that produces 8,000,000 cells/in.². They have maximum on-resistances as low as 8 m Ω , and are aimed initially at automotive applications. The 8-m Ω SUB60N06-08, 14-m Ω SUB60N06-14, and 18-m Ω SUB50N06-18 come in TO-263s. The 14- and 18-m Ω devices also come in the TO-220. The 8- and 14-m Ω FETs can carry 60 A maximum continuously while the 18-m Ω units carry 48 A. Peak pulsed drain current for all five is 240 A maximum. Future versions will be in Siliconix's 8-pin TSSOP Lite Foot. Call (800) 554-5565, ext. 30; or (408) 988-8000, ext. 30.
- *A 30-V MOSFET in a TO-220 that handles 70 A continuously.* Harris Semiconductor's RFP70N03 n-channel MOSFET sports maximum on-resistance of 10 m Ω with a V_{GS} of 10 V. It switches 30 V and 70 A in just 205 ns, has maximum peak-drain current of 200 A, and a maximum diode reverse-recovery time of 125

ns. Maximum power dissipation is 150 W. With 5 V of V_{GS} , on-resistance typically runs under 40 m Ω while continuously passing 40 A. In lots of 1000, it costs \$4.05 each. Within 30 to 60 days, Harris expects to announce a 60-V, 70-A, 14-m Ω FET in the D₂ package. Call (800) 4-HARRIS, ext. 7076.

- *A 50-V p-channel TO-220 MOSFET that passes 50 A.* International Rectifier's p-channel IRF4605 is designed for high-side switching without any bootstrap or charge-pump circuits. With a V_{GS} of -10 V, it can pass 50 A continuously and has maximum on-resistance of just 18 m Ω . IR will announce within 30 to 60 days a dual n-channel FET in an 8-pin SOIC, dubbed the IRF7301. Rated at 30-V breakdown, each die provides a maximum on-resistance of 50 m Ω with a V_{GS} of 4.5 V, rising to 80 m Ω at a V_{GS} of 2.7 V. Capable of handling 5 A, its process has an $R \times A$ of < 2 m Ω -cm² based on a cell density of 7 million cells/in.². Call (310) 322-3331, ext. 2529.

- *15-V p-type FETs in SOT-143s that control 200 mA in 0.01 in.².* Micrel's TinyFET MIC94030/94031 are 15-V "power" MOSFETs. They're basically "giant" logic-type, lateral, p-channel FETs with an on-resistance of 750 m Ω when fully enhanced with a V_{GS} of -4.5 V. They still provide an

on-resistance below 1 Ω with a V_{GS} of -3.3 V, and will operate down to -2.7 V. Crammed into a SOT-143 (a 4-pin SOT 23), the devices carry a footprint of just 0.01 in.² of pc-board area. While the MIC94030 is a basic 4-lead MOSFET, the MIC94031 contains an internal gate-pull-up resistor. The 4th lead in both devices connects to the substrate independent of the source lead, adding control, improving heat dissipation, and making analog-switch applications practical. In lots of 1000, they cost \$0.71 each. Call Marvin Vander Kooi, (408) 944-0800.

- *60-V/15-A and 38-V/50-A FETs that fit into DPAKs and TO-220s, respectively.* These four Motorola p-channel DMOSFETs—the MTD20PO6HDL, MTD-20PO3HDL, MTD50PO3HDL, and MTP50PO3HDL—can be fully enhanced with 5-V logic. They're based on a 6,000,000-cell/in.² process that provides a typical $R \times A$ as low as 1.7 m Ω /cm². With a $V_{GS(on)}$ of -5 V, they feature respective $R_{DS(on)}$ s of 150, 90, 30, and 30 m Ω ; voltage ratings of 60, 30, 30, and 30 V; and drain currents of 15, 18, 50, and 50 mA. The first two come in DPAKs, the third in a D²PAK, and the fourth in a TO-220. In production lots, the MTP50PO3HDL costs \$2.52 each. Motorola will later introduce a

CELL-BASED POWER SWITCHES

Semiconductor (then RCA) announced what they called logic-level FETs (RCA gave them the acronym L² FETs). They were designed and specified to be enhanced with just 5 V of gate-to-source voltage (V_{GS}).

Both International Rectifier and Motorola soon followed suit. Generally speaking, these FETs had breakdown voltages in the range of 50 or 60 to 100 V, although Harris now offers devices with ratings to 200 V. Some early L² FETs, albeit in large packages such as the TO-247, could handle up to 50 A. However, they didn't find homes in the computer world or in low-voltage switching power supplies. That's because in most applications, the L² FETs still

require high-current drivers for their highly capacitive gates. The drivers, which usually run off at least 15 V, easily provide the 10 V needed to turn on the lower-priced conventional n-channel FETs produced in large volumes for low-voltage switching power supplies.

But these 60-V, high-current L² FETs did find homes as static switches in automotive applications. In automotive tasks, their 60-V breakdown rating handles "load dump." And the need for only 5 V of drive ensures operation regardless of how low the battery voltage drops. Here, these FETs are comfortable driving solenoids, high-current contactors (relays), lamps, and even motors.

However, the need for efficient, low-voltage switches that turn on hard with gate-to-source voltages of 5 V or less—brought on by portable battery-powered systems—fostered an increased demand for such devices. This has resulted in a number of impressive technology advances.

LOWER ON-RESISTANCE

Lower on-resistance and its attendant lower forward voltage drop and conduction loss represents the "holy grail" strived for by today's semiconductor power-switch designers. Multiplied by the load current, on-resistance results in the forward voltage drop and, ultimately, conduction losses (the product of the forward

number of n- and p-channel power FETs based on its 6,000,000-cell/in.² processes, including additional 30- and 60-V FETs in the aforementioned packages with current ratings up to 75 A at 60 V. Motorola also will be announcing 100-A/100-V devices in the TO-264 and 100-V/215-A FETs in the TO-227 (ISOTOP). Others on the way include a variety of 12-, 20-, 30-, and 50-V p- and n-channel singles and duals, as well as complementary duals, in the SO-8. Future versions will see a range of 20- to 100-V devices in the SOT-223. Call Scott Delaney at (602) 952-4103.

• *A family of power p- and n-channel and CMOS power FETs in 8-pin SOICs.* National Semiconductor's 15-member family comes from a process providing vertical DMOSFETs with 5,000,000 cells/in.². It consists of single and dual n- and p-channel FETs as well as duals with one p and one n channel (power CMOS). On-resistances are specified with a V_{GS} of 10 and 4.5 V. For example, each FET comprising the dual 60-V NDS9948 has an on-resistance of 250 m Ω with 10 V V_{GS} and double that at 4.5 V V_{GS} . Voltage ratings run from 20 to 60 V. National expects to take advantage of its 1- μ m CMOS processes to raise power-FET cell densities. Future devices should operate with en-

hancement voltages of 5 V or less and come in smaller packages (the TSSOP is being considered, for example). Call Allan Ankerbrand at (408) 721-5710.

• *60-V vertical DMOSFETs in SOT-23s that sport 6- Ω on-resistance.* Supertex's p-channel TP2106K1s can be turned on with conventional 5-V logic and have minimum on-resistances of 6 Ω when enhanced with -10 V while passing 500 mA. At a V_{GS} of -5 V, minimum on-resistance rises to 10 Ω while passing 50 mA. These are the lowest on-resistance p-channel MOSFETs in SOT-23s. Power dissipation is 360 mW at 25°C. With a V_{DS} of 25 V and -10 V V_{GS} , minimum drain current runs 600 mA. Maximum turn-on delay, rise time, turn-off delay, and fall time run 6, 8, 9, and 8 ns, respectively. While the body-drain diode can handle 600 mA, the diode can't keep up with the FET—its reverse recovery time is typically 400 ns. In lots of 1000, the TP2106K1 costs just \$0.35. Call Dilip Kapur at (408) 744-0100.

• *A 60-V DMOSFET array that builds or drives H- and 3-phase bridges.* Texas Instruments' TPIC5601 complete 60-V, 3-phase bridge/bridge driver comes in a single 20-pin wide-body SOIC. It's the most complex of five ICs forming the second release of

members from the Power+ Array family. New family members consist of three, four, or six 60-V, n-channel DMOS power FETs on a single chip—a simple power IC. All members contain lateral rather than vertical DMOSFETs, thus the multiple transistors are self-isolated from each other. All devices come in SOICs and/or DIPs. The TPIC5601 comes in a 20-pin wide-body SOIC. It contains six FETs, three with a common-source connection to form the low-side switches in a 3-phase bridge. The other three are completely independent so they can form the bridge's high-side switches. The on-resistance of each FET is a maximum of 350 m Ω and each can take a maximum continuous current of 1.7 A. In lots of 1000, it goes for \$2.40 each. The TPIC5404 is similar to the TPIC5601; however, with its four 350-m Ω FETs it's aimed at full-bridge tasks. Each FET can handle at least 2 A continuously. It comes in a 16-pin DIP or the 20-pin wide-body SOIC. In lots of 1000, it goes for \$1.60 each. The TPIC5302 contains three independent 350-m Ω FETs each rated at 1.4 A continuously. It comes in a 16-pin SOIC. In lots of 1000, the device goes for \$1.20 each. If you desire further information, call (800) 477-8924, ext. 4500. Be sure to refer to SLI24.

CELL-BASED POWER SWITCHES

voltage drop and the load current). Since International Rectifier first announced cell-based FETs about 15 years ago, the $R_{DS(on)}$ of available, low-voltage, FETs has dropped by at least an order of magnitude in successive generations of processes. One should note too, that the attack on $R_{DS(on)}$ is far from over.

In reality, the challenge for the vertical DMOSFET designer is to improve the FET's specific on-resistance—that is, to decrease the $R_{DS(on)}$ per unit area of silicon (the resistance seen between the FET's source and drain terminals divided by the area of the die). Rather than use specific on-resistance (a legitimate unit of measure), the industry tends to employ the "resistance-area product" or " $R \times A$ " as its figure of merit for the normalized $R_{DS(on)}$ of FET die—regardless of size—coming off a particular process or processes.

Like specific on-resistance, minimum $R \times A$ is the goal. According to International Rectifier, the past 15 years has seen $R \times A$ drop from $12 \text{ m}\Omega\text{-cm}^2$ to $2.2 \text{ m}\Omega\text{-cm}^2$, and next year FETs based on $R \times A$ products of $1.2 \text{ m}\Omega\text{-cm}^2$ are likely.

Looking at a simplified cross-section model of a cell in a typical n-channel vertical DMOSFET reveals that about a dozen resistances in series make up its on-resistance (Fig. 1). Advances in reducing $R_{DS(on)}$ have come about by attacking these resistances separately and in concert (see "Power MOSFET and IGBT basics," p. 64).

The package resistance includes bond wires, the leadframe, and the leads (surface mount) or pins (through hole). The source metal on the die ties the sources of all the cells together. The channel resistance— R (channel)—prevents drain-to-source conduction when V_{GS} equals zero, just as in any enhancement-mode FET (junction or MOS). By applying sufficient V_{GS} , the p-type silicon in the channel turns into n-type silicon and the channel drops to a very low resistance.

The model of the vertical DMOS-

FET is modeled as a conventional low-voltage "lateral" MOSFET, with its channel turned on by the externally applied gate-to-source voltage (Fig. 1a). In this model, the lateral FET drives a higher-voltage "vertical JFET" connected in a cascode configuration (Fig. 1b). In fact, more complex versions of this model created over 10 years ago by Frank Wheatley, H. R. Ronan, and Gary Donley at RCA can be used in DMOSFET Spice simulations (this model and several others are now in the Harris MOSFET databook as application notes).

When the gate of the "lateral"

source, channel, and accumulation resistance, and then vertically through the JFET, the spreading, bulk, and substrate resistance, and finally to the drain metal on the die's bottom. The cells can be of any shape, as long as it optimizes packing density (to minimize $R \times A$). For example, Motorola employs square cells, while International Rectifier uses hexagonal cells (thus their trademark "HEXFET"), and some designs employ stripes. Regardless of cell shape, the channel surrounds the accumulation region, the source material surrounds the channel, and the p⁻ body material (a p-well) surrounds the JFET region.

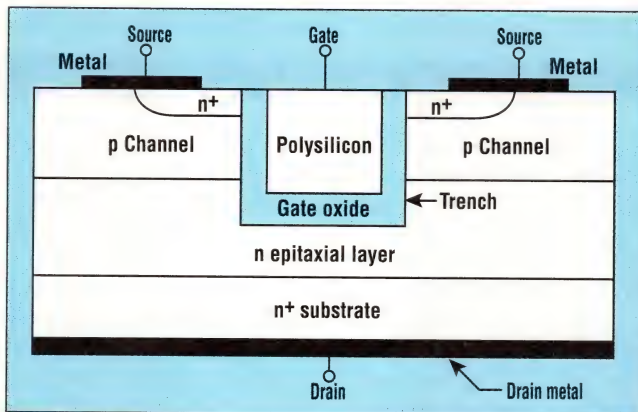
As noted earlier, not only do major differences separate high-voltage and low-voltage MOSFETs, but the latter in particular have responded well to attacks on $R \times A$. This was accomplished primarily by reducing the size of the individual FETs forming each cell, which raises cell density (the number of cells per square inch of silicon). Whereas early International Rectifier FETs employed on the order of 500,000 cells/in.², the company as well as Harris, Motorola, Siliconix and Na-

tional Semiconductor have announced FETs employing 5,000,000 to 7,000,000 cells/in.² to achieve $R \times A$ products of less than $2.5 \text{ m}\Omega\text{-cm}^2$.

HIGHER CELL DENSITY

Increasing the cell density by cutting cell size attacks several of the individual series resistances. It most affects the channel resistance, which easily forms about half the $R_{DS(on)}$ of a low-voltage FET. And $R \times A$ drops almost directly as cell density climbs. Upping cell density also reduces the n⁺ source resistance, the accumulation resistance, and even the spreading resistance.

Several other process advances increase the $R \times A$ product. For example, employing shallower junctions for the p well and the source implant not only lowers the channel and spreading resistance, but it shortens the JFET, diminishing its resistance. Reducing gate-oxide thickness im-



2. EMBEDDING THE GATE of a vertical DMOSFET deep within its structure lowers the on-resistance by eliminating the JFET region.

nMOS FET is positively biased relative to the n bulk silicon, an accumulation layer— R (accumulation)—forms in the n region below the gate. This accumulation layer becomes the drain of the "lateral" FET and the source of the "JFET." The JFET channel now consists of the region between the p⁻ body diffusions that act as the gate of the "JFET." The channel's drain connects to the spreading and bulk regions, forming the drain region of the basic vertical DMOSFET. Produced in the epitaxial layer, the bulk and drain regions must stand off most of the drain-to-source voltage applied to the vertical DMOSFET.

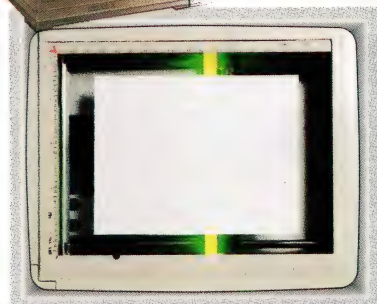
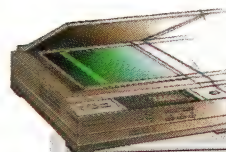
Consequently, the current flow in each cell is "T-shaped" (from which Motorola created the T-shaped logo for its power FETs and trademarked them "TMOS"). The current flows laterally from the source metal on the top of the die, through the

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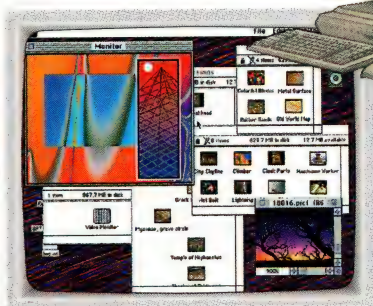
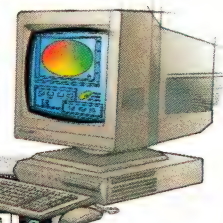
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proves the enhancement for a given V_{GS} , although it usually decreases the maximum V_{GS} .

Most of the action in a power MOSFET occurs within the top few hundred microns of the surface. The remainder (the substrate) merely acts as a supporting structure during processing, testing, and packaging. However, because most power FETs are built on 6-in. wafers that are about 0.5 mm (20 mils) thick, high-resistivity substrates can significantly impede the goal of ultra-low on-resistances. As a result, FET suppliers are turning to low-resistance substrates, in which arsenic doping re-

places the usual antimony doping. Further reduction in $R \times A$ is achieved by using thicker source metal and multiple or thicker bond wires, or even by moving to gold bond wires.

Can anything be done to drop the $R \times A$ for FETs rated for drain-to-source voltages much above 100 V? Yes. As the rated breakdown voltage of a FET climbs above 100 V, the epitaxial material (epi) becomes responsible for greater portions of the $R_{DS(on)}$. Because it must stand off most of the drain-to-source voltage, the epi material can represent 70% of $R_{DS(on)}$ for 250-V devices, and over

90% for 1000-V FETs.

It's been said that trying to reduce the epi resistance is, in effect, "fighting physics." High-resistivity silicon must be used to stand off the high voltage. Over the last few years, however, the quality of the epi material has improved. In particular, the tolerance on both its thickness and resistivity has increased. Consequently, for example, FET designers need not specify a higher voltage epi (with its higher resistivity) than necessary to ensure they get the voltage-handling ability required by a particular device.

In the 250-V FET arena, about 20%

POWER MOSFET AND IGBT BASICS

Power MOSFETs and their insulated-gate bipolar-transistor (IGBT) offspring are divvying up a major share of the medium and low-power solid-state power-control applications, many of them new. Although these devices are over a decade old, it's worthwhile noting some of their basic features, characteristics, and differences, and their relative advantages and disadvantages.

A power MOSFET basically looks and acts like a giant FET with voltage and current ratings far exceeding those of typical MOS logic devices. But, like the logic MOSFET, it's a majority-carrier device, looks like a resistance when turned on, and turns on and off fast. Most MOSFETs are double-diffused vertical devices in which the current flows between the top and bottom of the die. However, a few companies are putting large lateral pMOS and nMOS FETs in tiny packages like the SOT-23.

The IGBT, on the other hand, looks like a bipolar power transistor driven by a MOSFET connected as a source follower. It provides the high input impedance of the MOSFET with the low forward-voltage drop—at high voltage—of the power bipolar transistor, which results from the injection of minority carriers. When turned on, it looks like a diode.

However, although the IGBT turns on fast, the need to sweep out the minority carriers slows down the turn off time, severely limiting switching rates.

Both the MOSFET and the IGBT are true ICs. Both consist of hundreds to hundreds of thousands of individual transistors, called cells, all connected in parallel. Both are built on fine-geometry 5- or 6-mask IC processes, many of them older (1 to 1.2 μm) DRAM fabrication processes.

Due to the approximately 2:1 superior mobility on n-type devices, n-channel power FETs dominate the available devices, because they need about half the area of silicon for a given current or voltage rating. However, as the technology matures, and with the demands of power-management applications, p-channel devices are starting to become available. They make possible power CMOS designs and eliminate the need for special high-side drive circuits. When a typical n-channel FET is employed as a high-side switch running off a plus supply rail with its source driving the load, the gate must be pulled at least 10 V above the drain. A p-channel FET has no such requirement.

While the low on-resistance of low-breakdown-voltage MOSFETs represents a major strength, the high on-resistance of high-voltage MOSFETs is a

weakness. That's because either thicker silicon, or silicon with higher resistivity, must be used to stand off higher voltages. As a result, for a given die size, the on-resistance rises as about the 5/2 power of the voltage rating. Or to put it another way, to maintain constant on-resistance as the voltage rating rises, the silicon area must increase as the 5/2 power of the voltage rating.

The IGBT is successfully challenging the high-voltage FET. That's due to the injection of minority carriers, which permits fabrication of a 500-V die significantly smaller than a 500-V MOSFET offering the same voltage drop at the same rated current. Moreover, die size doesn't increase with voltage rating. But, process techniques that cut turn-off time tend to raise the forward voltage drop.

The reverse diode between the FET's drain and source also distinguishes it from the IGBT. In many applications, such as when switching an inductive load, the diode can act as a "snubber" or "free-wheeling" diode, eliminating the need for an external device. Though the IGBT has no such diode, suppliers often add them in the package. However, while the diode in some FETs offers reverse recovery as fast as the FET can switch, not all FETs provide that kind of speed.

CELL-BASED POWER SWITCHES

of the $R_{DS(on)}$ comes from the JFET. But so far, no supplier has attacked that phenomenon. That could be because no one sees a way around that situation, or maybe because it's being attacked by the IGBT as it climbs in speed without increasing its forward drop.

JFETs IN DMOSFETs

In the under-100-V area, however, the MOSFET's JFET is under attack. Long the subject of conference papers from academia and companies, Siliconix has moved to a 60-V "trench" process (Fig. 2). Borrowing from memory technology, the company's technologists inserted the gate deep into the bulk region by isotropically etching a vertical trench, oxidizing its side walls, and back-filling the oxide-walled trench with polysilicon. The vertical p-channel surrounds the gate's sidewall. The trench gate not only eliminates the JFET and its resistance from the device, but it also significantly reduces

the spreading resistance in the epi layer while increasing potential cell density. Now, current flows almost vertically between source and drain.

FET on-resistance is like most real-world problems. The trick is to find the optimum value or configuration for its solution. For example, the push for higher cell-density levels faces some limitations. If the cells are packed too tightly, the JFET resistance starts to climb. Thus, by eliminating the JFET altogether, trenching also permits greater cell density.

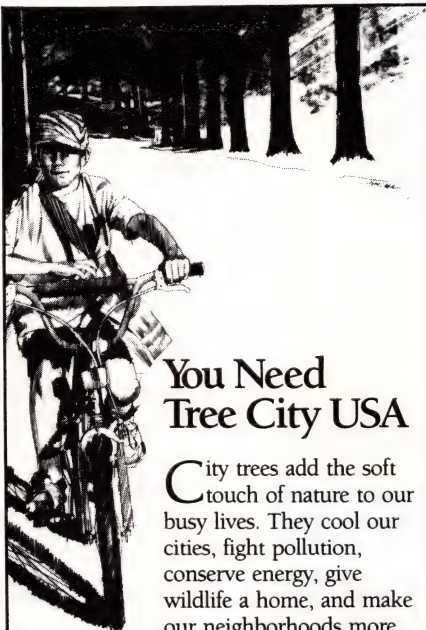
While the conventional DMOSFET has moved to voltages of 30 V and lower to increase cell density and lower JFET resistance, the trenching technique will find homes for devices rated at 60 V or more. In these cases, the JFET resistance contributes a larger share of the on-resistance. It will be interesting to see if trench technology moves to higher-voltage FETs to combat the on-

slaught by the IGBT as its switching rate climbs.

Upping cell density faces other limiting conditions. If the cells are too small, channel resistance actually goes up. In addition, dropping contact size raises contact resistance; and too shallow diffusions raise the p well (body) resistance.

Because most suppliers of MOSFETs and IGBTs are one and the same, the battle isn't between competitors in the marketplace. Instead, the battle is waged between technologists and marketers within companies. But if one supplier surprises the world with an affordable 250-V FET that can come close to an IGBT's forward drop—and switch ten times as fast—that company may have a tiger. □

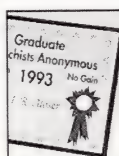
HOW VALUABLE?	CIRCLE
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MODERATELY	538
SLIGHTLY	539



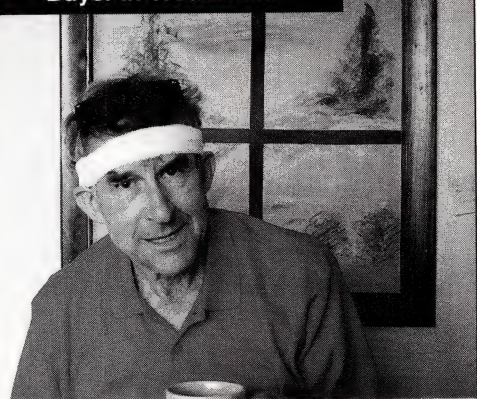
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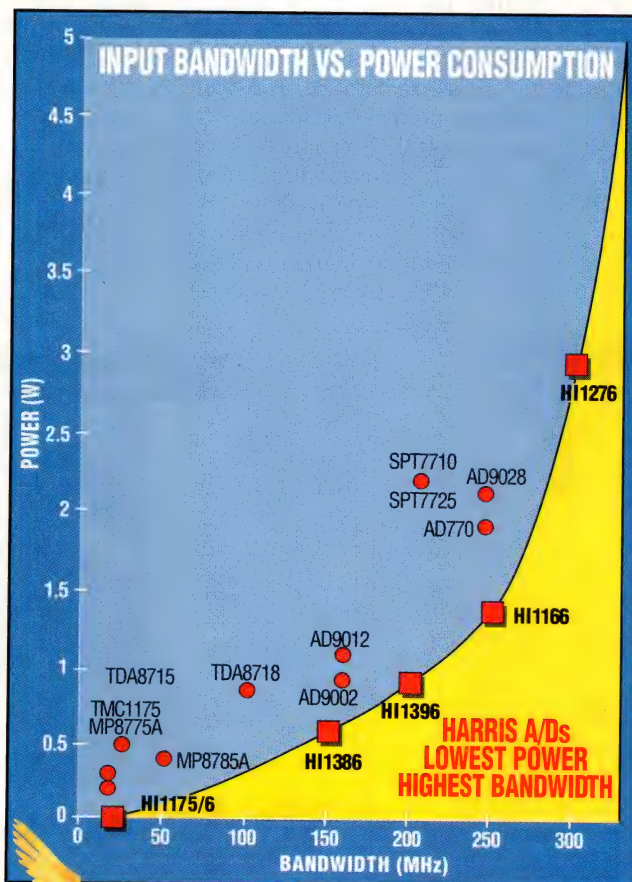
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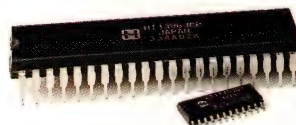
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OPTIMIZE MICROPROCESSOR SUPERVISORY CIRCUITS

HERE'S SOME TIPS FOR DESIGNING RELIABLE CIRCUITRY FOR V_{CC} MONITORING, BATTERY BACKUP AND WATCHDOG FUNCTIONS.

LEN SHERMAN and DOUG VARGHA
Maxim Integrated Products,
120 San Gabriel Dr., Sunnyvale, CA
94086; (408) 737-7600.

All microprocessor-based systems require support circuitry to prevent erratic operation during startup and when going into or coming out of a power-down mode. This circuitry can consist of no more than a simple power-on reset generator, or may be sophisticated enough to include such diverse functions as backup-battery management, memory-write protection, and watchdog timing to monitor software execution.

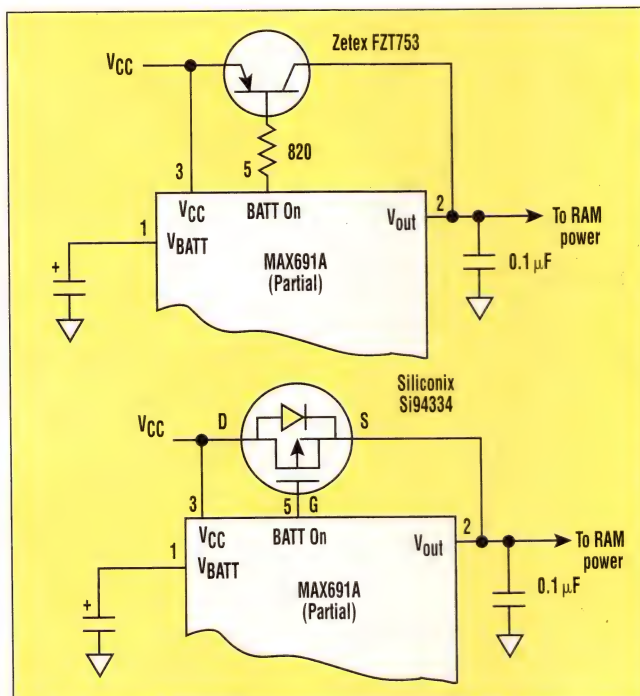
Often, these functions can be provided by a system supervisory circuit—a specialty IC designed to provide common housekeeping functions. In a number of applications, though, digital designers find that a straightforward application of the circuit isn't enough to make it do everything needed. Sometimes just a reinterpretation of specifications is all that's required; other times additional circuits must be added around the supervisory circuits.

Many common problems that arise in power management have relatively simple solutions. This article examines some practical solutions that require more than simply dropping in a supervisory chip. These solutions go beyond the basic operating conditions and typical cases usually found in the manufacturer's data sheet.

BACKUP MANAGEMENT

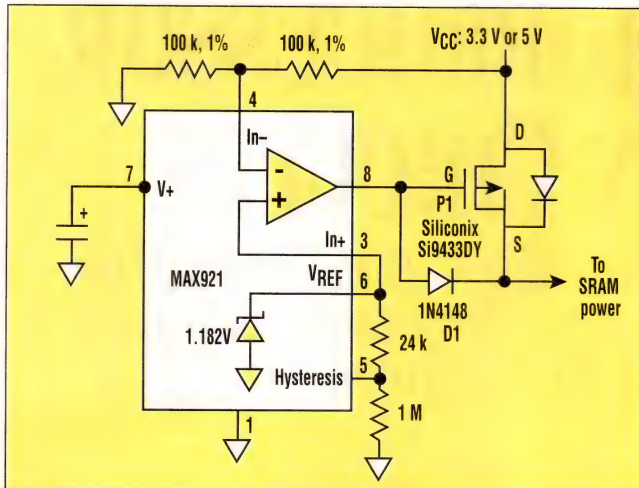
Backup batteries assure that critical circuits such as the memory and real-time clock receive uninterrupted power when the primary power source is removed. In many older as well as very low-cost systems, diodes are typically used for backup-battery switchover. But those diodes may have an excessive forward voltage drop or high leakage currents, resulting in an inefficient solution.

Microprocessor supervisory circuits can eliminate such inefficiencies because they use integrated CMOS switches. The MAX691A is typical of such integrated circuits—it employs low-resistance ($0.8\text{-}\Omega$) switches to han-



1. EXTERNAL, low-loss transistor switches enable the MAX691A to deliver more RAM current for normal operation. Either a pnp bipolar transistor (top) or a p-channel MOSFET (bottom) can be used as the external current switch for the RAM array (an internal switch handles the backup-battery current).

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2. BY SOURCING SRAM CURRENT from the battery via the comparator output, this backup circuit has no trouble with battery voltages that exceed V_{CC} . The low-current MAX921 comparator controls the p-channel MOSFET, which cuts off the main supply and switches in the standby source.

dle the V_{CC} load current when the RAM is active, and a smaller (15- Ω) switch connects to the battery during standby operation. The main V_{CC} switch can turn on or turn off loads of up to 200 mA.

Inspecting various RAM data sheets may lead a design engineer to the conclusion that a 200-mA rating isn't high enough to supply the required load current. However, this conclusion could simply be a misinterpretation of the data sheets.

For example, consider the conditions for maximum supply current in a static RAM (SRAM): the manufacturer's operating-current specifications for such devices usually assume a minimum cycle time and a 100% duty cycle. The specifications also assume that read and write cycles occur at the maximum rate. Such conditions often apply for high-speed processors, and for them, the RAM currents actually approach the specified limits.

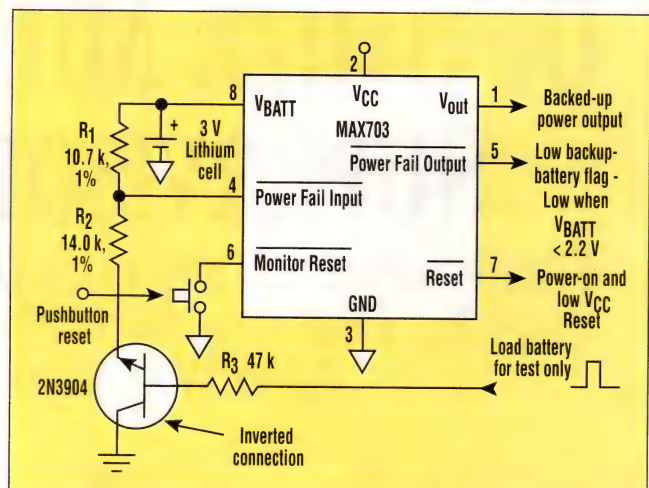
SLOWER RAM CYCLES

Processors and microcontrollers operating at lower rates (1 to 4 MHz), however, produce slower RAM cycles that draw less current. This current often can be handled by supervisor ICs with internal current switches, which might otherwise seem inadequate in terms of the maximum specified RAM current.

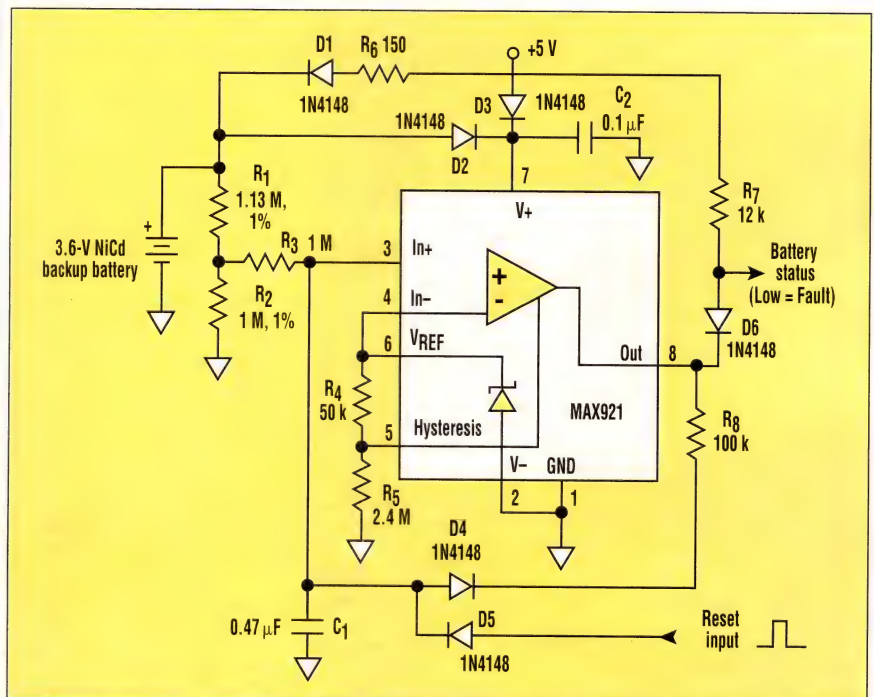
Some (not all) SRAM manufactur-

ers make it easier to derate their products' supply current by specifying it at longer cycle times (1 μ s, for instance) in addition to the minimum. By derating the speed, the operating current at 1 μ s can drop to less than one-third of its value at the memory's minimum cycle time. SRAMs aren't alone in the

derating game—dynamic and pseudo-static RAM (DRAM and PSRAM) operating currents also can be derated based on the access rate or operating clock speed. When idle, though, DRAMs and PSRAMs draw more current. However, that drawback is often offset by the fact that they're

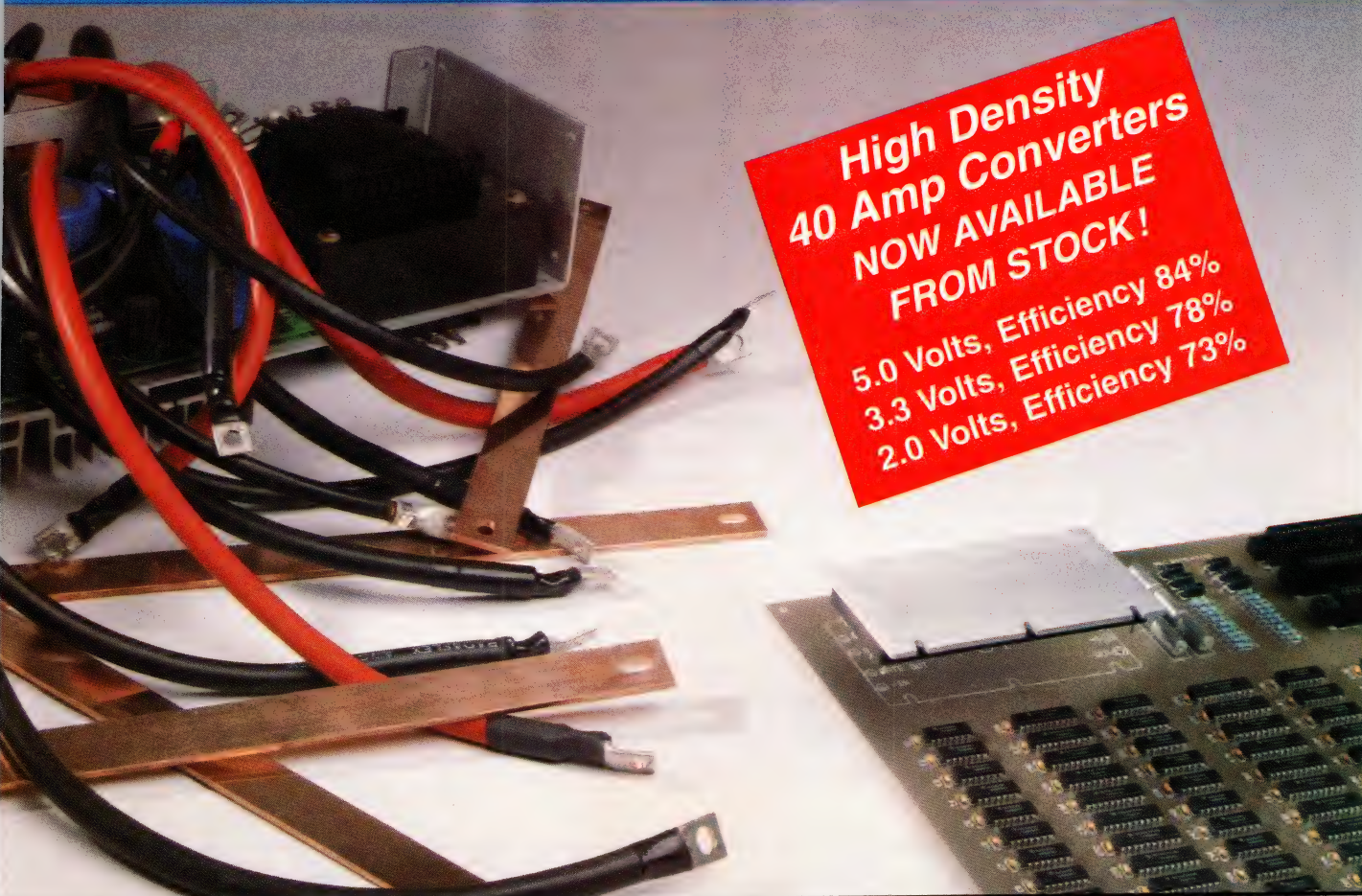


3. TO ENSURE THAT THE BACKUP battery can support its standby load, the MAX703 comparator and inverted external npn transistor lets the microprocessor load the battery. This approach allows the battery's output voltage to be checked under loaded conditions.



4. AS LONG AS THE BATTERY VOLTAGE STAYS ABOVE 2.4 V, this analog latch (based on the MAX921 micropower comparator) keeps the Battery Status output high. When V_{CC} returns, the Battery Status will be low only if the battery ever fell too low (below 2.4 V) during a power outage. The results were obtained using a NiCd battery while the power was out.

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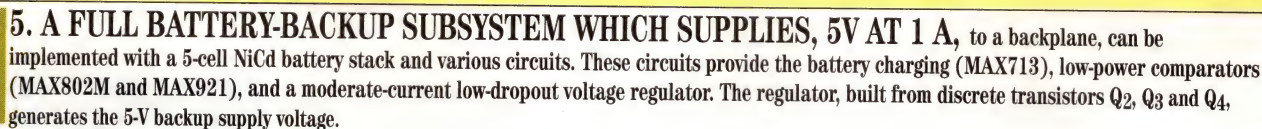


The transistor costs less, but the MOSFET is generally preferred. This is especially true in 3.3-V systems, now that PMOSFETs with low gate thresholds are available. The MOSFET offers a lower forward drop ($0.1\ \Omega r_{DS(on)}$) and it eliminates base-current losses. What's more, with the inverted configuration shown, the MOSFET's drain-source body diode blocks the unwanted flow of current from output to V_{CC} during backup.

One way around this dilemma is to use a low-current comparator and a small number of discrete components for switchover (*Fig. 2*). With such an approach, the comparator's output controls MOSFET P₁, as well as provides backup power when V_{CC} fails. With V_{CC} greater than 3.0 V (V_{CC}

In addition to providing backup-battery switchover, microprocessor support circuitry also must verify that the backup battery is charged. Many supervisory circuits provide a comparator for this function. The comparator can signal a loss of the backup supply before it's needed. Also, while the main power is still present, the device allows time to replace or recharge the backup supply.

A simple comparator is adequate when the backup battery doesn't supply much current. However, other methods are required when the backup current is significant (hun-



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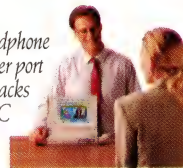
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dreds of microamperes to tens of milliamperes). A backup battery will exhibit significantly higher terminal voltages when unloaded than when it's heavily loaded. Therefore, the backup battery should be tested under load to verify that it will provide the necessary support during standby (Fig. 3).

To perform a test under load, the battery connected to a MAX703 supervisory circuit is loaded by a command from the host microprocessor, which grounds the R_1 - R_2 network via an inverted transistor. Typically, R_1 and R_2 would present a much higher impedance—and therefore, wouldn't load the battery, with R_2 returned to ground. Using lower-valued resistors allows the battery to be loaded as it being tested.

FETs can be used, but a small bipolar transistor (such as a 2N3904) is less expensive. The inverted configuration provides a small forward drop of only 2 mV. The transistor's beta is approximately unity, but for small loads (125 μ A) the base current also is small. A low output on pin 5, the Power Fail Output (PFO), indicates during a battery test when a battery voltage is below 2.5 V (other functions of this circuit include battery switchover and power-on reset).

WHILE YOU WERE OUT....

At times, more than just the immediate status of the backup battery is required—during long periods of unattended backup, just the knowledge that the backup battery ever went low could be important.

For instance, information concerning whether or not the backup battery was discharged excessively during a power failure, and then recharged when the power returned, could be useful. A simple comparator circuit couldn't detect that the backup battery had been low, and that data had possibly been corrupted.

To verify battery status without resorting to an intelligent charger, the battery can be monitored with an analog latch made from a micropower comparator (such as the MAX921) and a reference (Fig. 4). The "Battery Status" output, normally high, remains so during a power failure unless the battery voltage falls below 2.4 V. If the voltage should fall below 2.4 V,

the status output goes low and pulls the noninverting input to within a diode drop of ground.

The status output remains latched in the low state after the battery voltage returns to normal, serving as an indicator that something happened to the battery voltage which may have affected the memory. This information allows the system to verify memory contents and the battery before resetting the latch (by pulsing the "Reset Input"). Large resistor values for R_1 , R_2 , and R_3 minimize drain on the battery, while R_4 and R_5 bias the hysteresis input to provide 50 mV of comparator hysteresis. Those resistors simplify calculations because they set the hysteresis level independently of the comparator's trip thresholds.

BEYOND MEMORY BACKUP

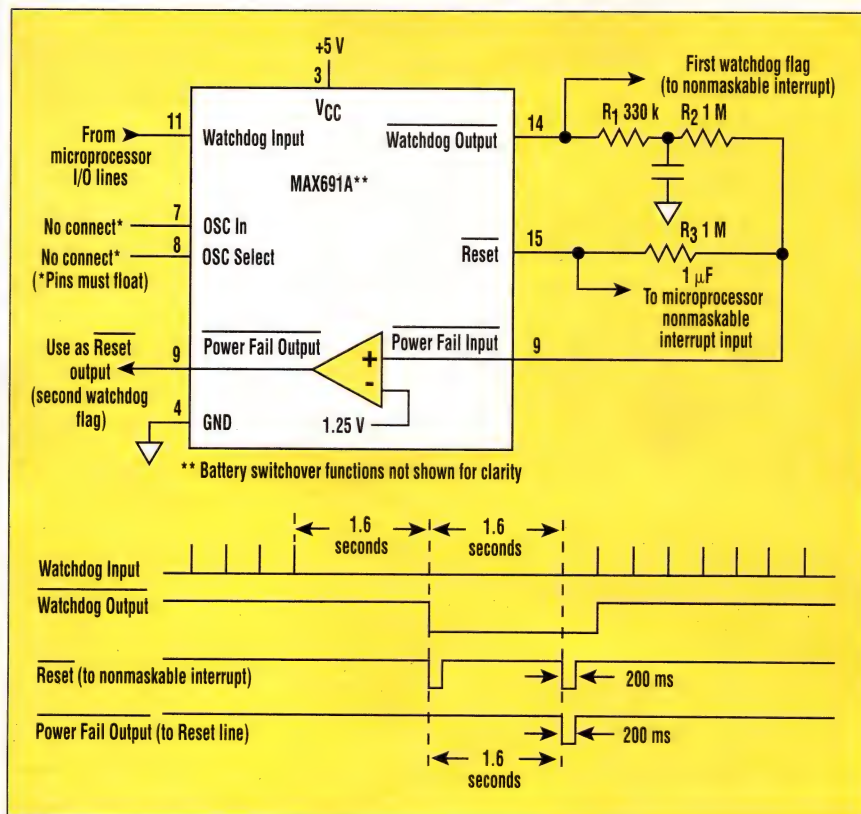
Microprocessor supervisory circuits with battery switchover can comfortably supply current to RAM and real-time clocks via the small batteries and switchover circuits discussed earlier. But special steps must

be taken by the designer if the system must do more than retain memory when the power fails. For example, if a system has to write large data files to a hard disk, or send data over a network to a file server after power is lost, the system will obviously require backup power comparable to that of normal operation.

In this case, a supervisory circuit can only provide switchover control and other housekeeping functions. Higher-power circuitry is needed to handle the current. In one such arrangement, a 5-cell NiCd or NiMH battery stack provides the substantial backup power (Fig. 5).

The circuit, using the component values shown in the figure, can supply 1 A during backup. Even more current can be delivered if components with higher power ratings are used. Alternatively, power requirements can be reduced by slowing down or turning off certain machine functions to avoid overloading the output during backup operations.

The supervisory circuit provides a "Backplane OK" signal, which in-



6. THE FIRST WARNING generated by this two-stage watchdog timer is a software reset to the microprocessor's NMI input (top). The second and subsequent watchdog timeouts produce hardware-reset pulses at the Power-Fail Output line (bottom).

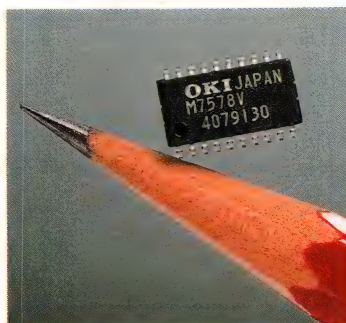
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MSM7578H/7578V/7579	4.75-5.25V	7578H/ μ -law 7578V/ μ /A-law selectable 7579/A-law	○		not needed	M.P.
MSM7570	4.5-5.5V	μ /A-law selectable	○	○	7570, 19.2/12.288MHz	M.P.
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forms the system that full-speed operation is safe (because the line-powered 5-V supply voltage is within tolerance). If the supply falls below 4.5 V, this signal (inverted) turns off the backplane switch (Q_1) and turns on Q_5 , activating a discrete-transistor, low-dropout regulator (Q_2 , Q_3 , and Q_4) that generates 5 V from the battery output.

Comparator U_2 helps prevent the battery damage that can accompany a deep discharge by sensing the battery voltage and asserting the "Battery OK" signal low.

Thus it generates a warning that lets the system perform its last-minute housekeeping duties before issuing a command (via relay K_1) to disconnect the battery. The battery is charged with a fast-charger circuit, U_3 .

TWO-STAGE WATCHDOG

A microprocessor-supervisor IC also handles the function of watchdog timer. Typical watchdog circuits monitor a system's software execution via activity on a logic or I/O line, asserting a reset or nonmaskable interrupt if the activity ceases for a predetermined time. This action assumes that a crash halts software execution, and that continuing activity indicates all is well.

It's important to consider that remote systems and critical control applications may require a two-layer watchdog—a feature that's not standard in supervisory ICs. In a two-layered system, the first watchdog failure triggers a nonmaskable interrupt (NMI) that resets the executing application program. Then, if software execution doesn't resume, the second failure triggers a hardware reset via the microprocessor's Reset input.

A single-IC approach can provide such a two-level watchdog timer (Fig. 6, top). When toggling stops at the Watchdog Input (WDI), the IC's timer waits 1.6 seconds and then pulls the Watchdog Output (WDO) and Re-

set lines low. WDO remains low until the next input transition at WDI, but Reset returns high after 200 ms. Until WDI changes state, WDO remains low and Reset issues a 200-ms negative pulse every 1.6 seconds.

Delay network R_1 - C_1 with summing resistors R_2 and R_3 performs a logic function that would otherwise require a second IC. Acting as summing resistors for the Power-Fail Input (PFI)

Basic supply-voltage monitors issue a microprocessor reset signal when the primary supply voltage (typically 5 V) falls below a specified minimum. One such approach to doing this uses a comparator and voltage reference. Other more useful circuits include a delay that provides time for necessary housekeeping tasks before the system resumes normal operation (assuming the power is restored).

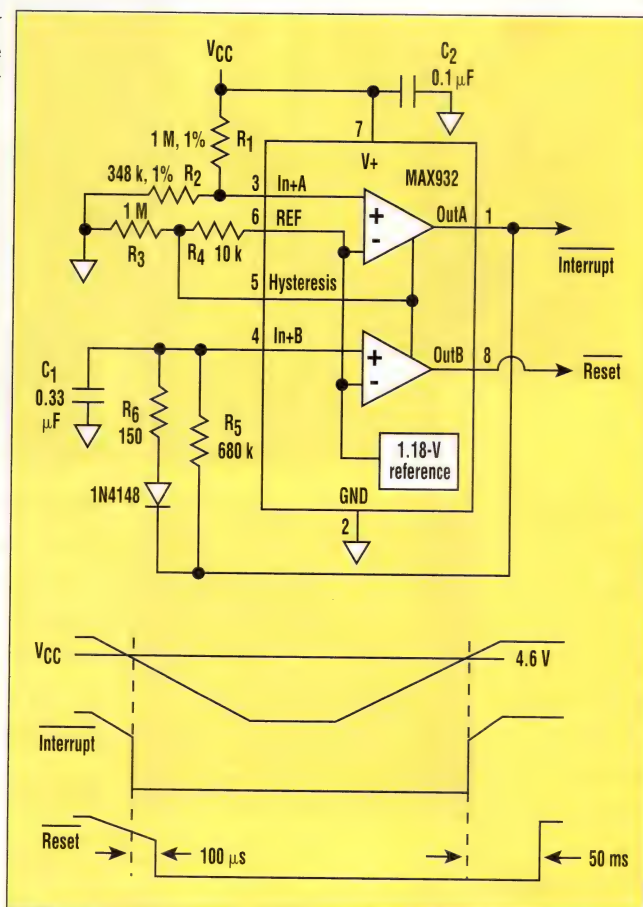
The simplest solution for this reset function is a single supervisory IC that eliminates the external components otherwise required for timing and for setting the voltage thresholds. Furthermore, the IC's factory-trimmed threshold often has greater accuracy than that of a discrete circuit (whose error includes the reference accuracy, comparator offset, and resistor tolerance). Thus, using a dedicated IC can eliminate the need for board-level trimming.

Although such supervisory chips are somewhat more costly than an RC network connected to the microprocessor-reset pin, their precise voltage monitoring, brownout safeguard, fast response, and other functions offer far more comprehensive protection. However, even the lowest-power supervisory circuits consume anywhere from 25 to 100 μ A of supply current.

Because battery operation may require the conservation of every microampere to maximize battery life, these supervisory circuits may not suffice. For applications that require minimal quiescent current,

a low-current dual comparator can perform the voltage monitoring and reset function while drawing only 6 μ A (Fig. 7).

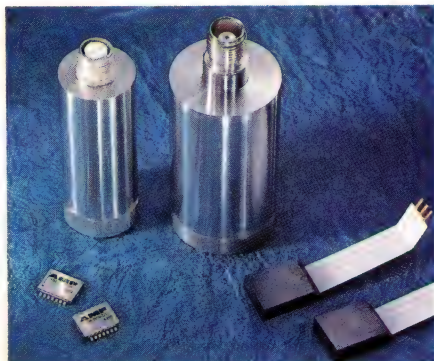
It also generates an interrupt output (INT) that precedes the Reset signal by 100 μ s. INT gives the processor an early warning, allowing the system to perform its housekeeping chores before the hardware reset takes place.



7. THIS MICROPOWER MONITOR based on the MAX932 draws a mere 6 μ A. It can issue an early-warning interrupt signal (INT) 100 μ s before the reset signal. A large bypass capacitor (0.1 μ F) connected to the comparator's positive supply pin holds up the voltage to the comparator long enough for the host processor to perform a controlled shutdown.

comparator, R_2 and R_3 assure that the Power Fail Output (PFO) remains high until both resistors see logic-low signals (R_1 - C_1 delays the low state at R_2). As a result, Reset issues a software reset following the first watchdog timeout, and PFO issues a hardware reset following each subsequent timeout (Fig. 6, bottom). If necessary, the duration of these nominal 1.6-second timeout periods can be adjusted.

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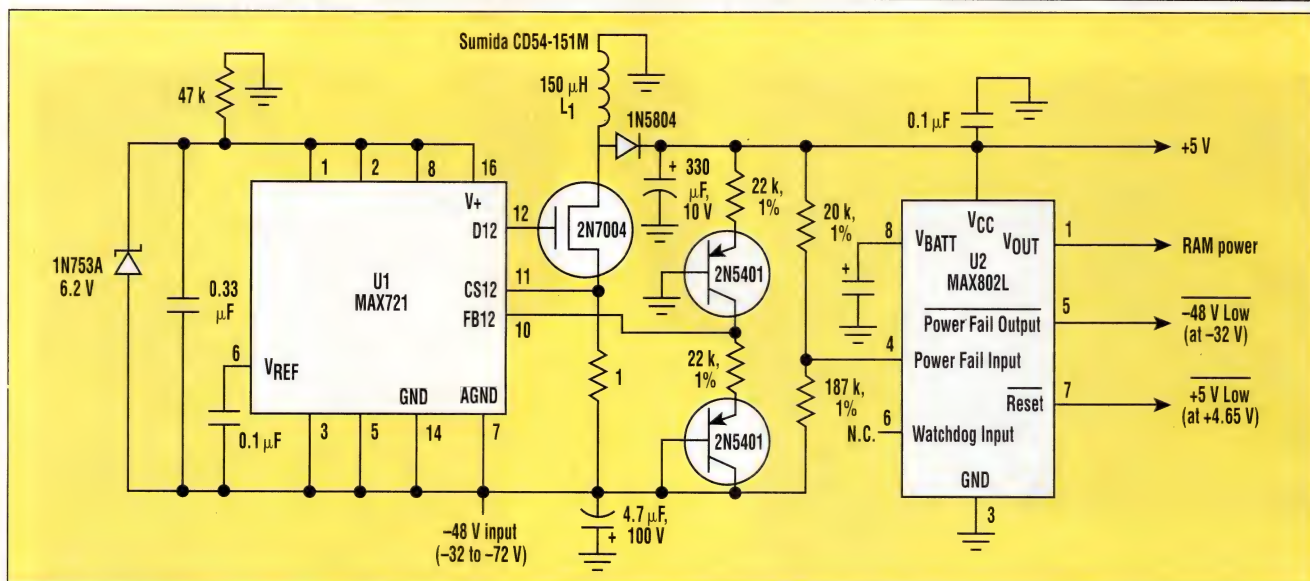
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8. BY MONITORING THE NEGATIVE source voltage for a 5-V dc-dc converter, the MAX802L comparator can deliver an early warning to the system if the negative supply starts to fail. The resistor divider, composed of a 20-k Ω and a 187-k Ω resistor (both within 1% tolerance) connected from the 5-V supply output to the negative supply, is the key to monitoring the negative supply.

For the dual-comparator circuit to work, V_{CC} must not fall too sharply between INT and Reset (as it will when the battery is abruptly removed). Therefore, a large bypass capacitor is needed to hold up V_{CC} until the processor can execute a clean shutdown.

The capacitor's value depends on the load current. With a 10-mA load and a 10- μ F capacitor, for example, V_{CC} drops only 0.1 V during the 100- μ s window between the INT and Reset signals.

MONITOR MULTIPLE SUPPLIES

In addition to keeping an eye on the main supply voltage, the power-monitoring circuits often have to keep tabs on additional voltages used in the system. Many systems not only rely on a stable V_{CC} , but count on other voltages to stay in tolerance as well. For instance, a low voltage supplied to a solenoid or motor might require a warning to the processor indicating that a valve could be partially open.

Another reason to monitor a voltage other than V_{CC} is to provide an early warning indication of supply failure. For example, assume a central-office battery stack serves as a main (or backup) source for a telecommunication system's negative-supply voltage. In addition, assume that voltage, in turn, is converted to

5 V by a regulated dc-dc converter.

It would be helpful if the supervisor could monitor both the 5-V level and the negative input voltage (-32 to -72 V, and -48 V, nominally). By monitoring the negative supply from which the 5-V level is derived, the system can get a slight advance warning of an impending crash in the 5-V supply.

Multiple comparators or a multichannel analog-to-digital converter can monitor multiple supply voltages. Comparators are usually preferred for fault monitoring. They respond more quickly, consume less power, and do the job without requiring (or assuming) that the system is operating normally. Many supervisory circuits include an extra comparator that does the job quite nicely.

MONITOR NEGATIVE VOLTAGES

Although the extra comparator on microprocessor supervisory circuits generally monitors only positive voltages, it's not strictly limited to that function. By slightly modifying the external circuitry, designers can also use it to monitor negative voltages (Fig. 8).

The external circuitry includes a resistor divider connected from the output to the extra comparator, with one end returned to V_{CC} instead of to ground (which is typically the case). That connection scheme allows a

negative voltage to be monitored.

Once the proper resistor values are chosen, when the negative supply falls to less than -32 V, the "-48-V Low" output from comparator U_2 (the MAX802L) activates a microprocessor interrupt that protects the memory contents before the 5-V supply can fall (and before a reset occurs). This circuit, though, has one drawback: The 5-V output must be in regulation because it serves as a reference for the -48-V sensing network. Comparator U_2 also protects the memory by switching the RAM power line from V_{CC} to a lithium backup battery, connected to the V_{BATT} pin. Switching regulator U_1 (MAX721) generates a 5-V level from the negative telecommunications supply. $\square$

Doug Vargha, an applications engineer at Maxim, holds a BSEE from the University of Washington.

Leonard Sherman, who serves as applications engineering director at Maxim, previously designed laboratory instrumentation with the technical staff at the Massachusetts Institute of Technology.

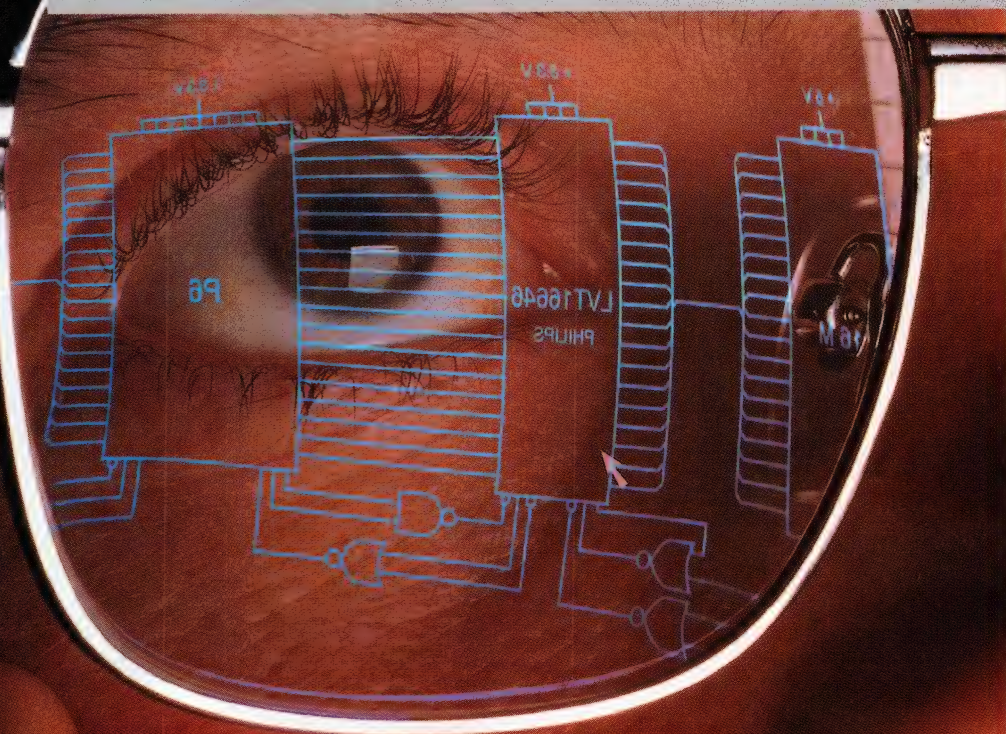
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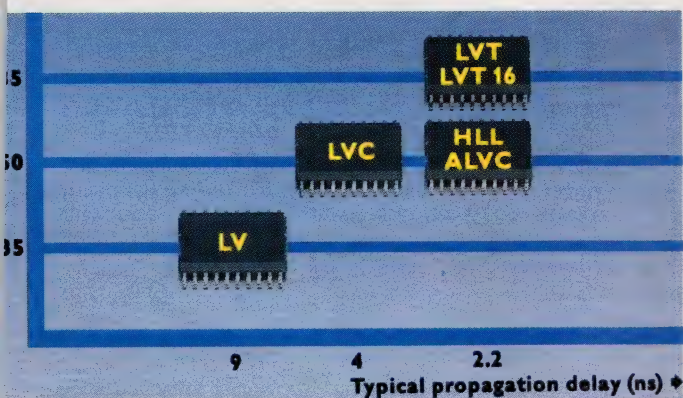
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CIRCLE 521 PROTECTION FOR H-BRIDGE DRIVERS

PETER SCHWARTZ

Linear Technology Corp., 1630 McCarthy Blvd.,
Milpitas, CA 95035; (408) 954-8400.

Built-in protection against overcurrent in an H-bridge dc motor driver can be achieved with dual-threshold current sensing. In the circuit shown (see the figure), two LTC LT1158s are employed as the core of a full-bridge dc motor driver. Using one current-sense resistor, protection is provided against overloaded, stalled, or shorted motors. For overloads and stalls, the circuit becomes a constant-current chopper, regulating the motor's armature current to a preset maximum value. For shorted loads, the circuit protects itself by

operating at a low duty cycle until the short is cleared.

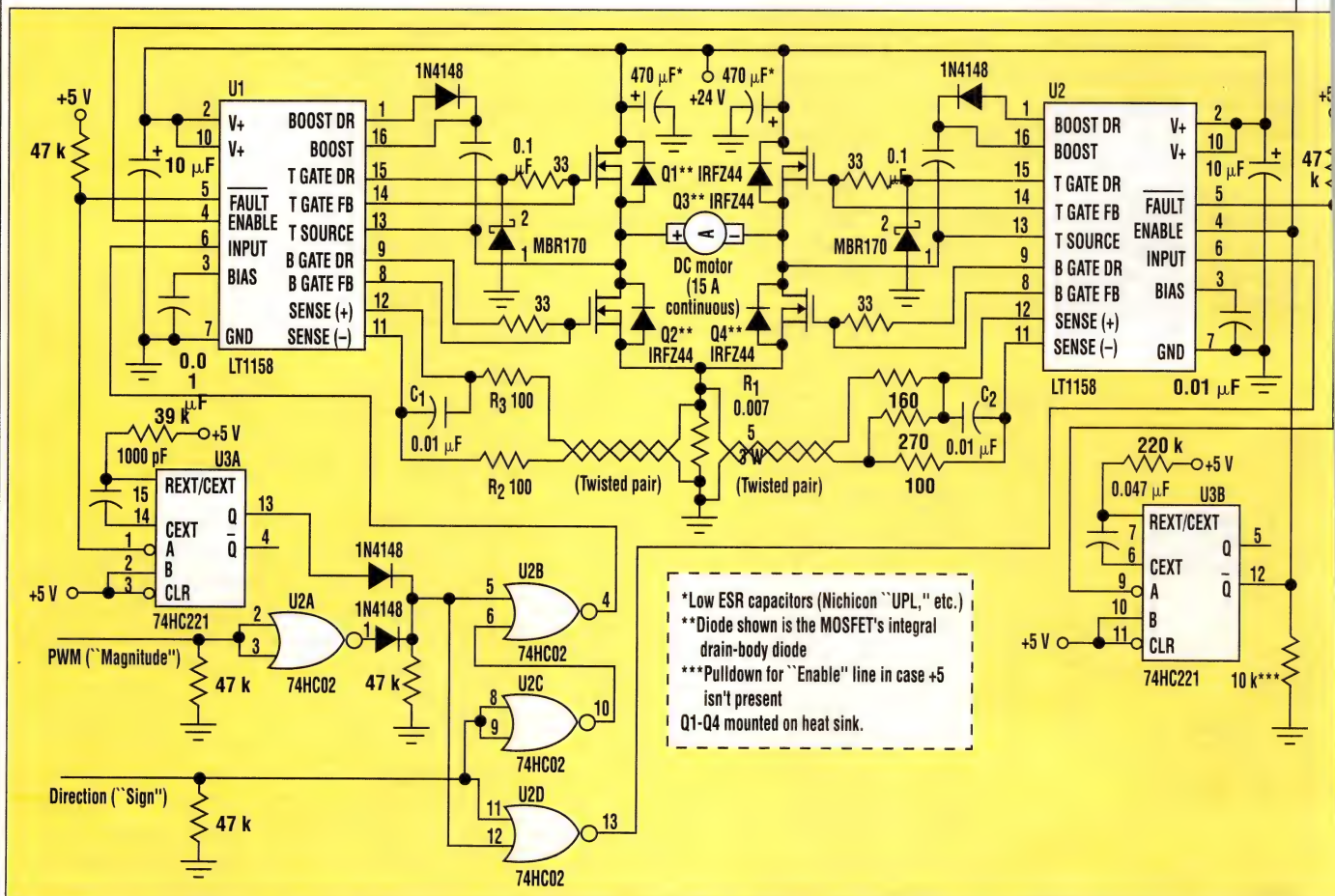
The LT1158 makes most of the functions required for driving power MOSFETs transparent to the user, as is the case with the "sign-magnitude" H-bridge shown in the figure. In addition, the LT1158 contains a comparator with a built-in 110-mV threshold voltage.

When two LT1158s are combined to make an H-bridge driver, their two comparators and a few extra components provide protection against motor inrush and overload currents, as well as keep the circuit safe in the

face of a shorted load.

Each comparator monitors the IR drop across one resistor (R_1) common to the sources of both lower MOSFETs. U1's Fault output activates a constant-current protection mode (for startup inrush and overloads, while U2's Fault output triggers protection against a shorted load. Given a maximum continuous motor current of 15 A, U1's comparator threshold of 110 mV determines R_1 : $V_{\text{Sense}(+)} \text{ of U1 must exceed } V_{\text{Sense}(-)} \text{ by } 110 \text{ mV}$ in order for Fault to go "low." Therefore, $R_1 = (0.110 \text{ V}/15 \text{ A}) \approx 7.5 \text{ m}\Omega$. The Fault pin of U2 is to go low if I_{R1} is $\geq 24 \text{ A}$, so a 1.6:1 voltage divider is added at U2's Sense(+) input. C_1 and C_2 filter any switching spikes that appear across R_1 .

If the motor is overloaded or stalled, its back EMF will drop, causing the armature current to increase at a rate determined primarily by the motor's inductance. Without protec-



AN H-BRIDGE DRIVER, COMPRISED OF TWO LT1158S AND a few extra components, will provide protection against motor inrush and overload currents, and keep the circuit safe against a shorted load. The circuit makes use of each LT1158's built-in comparator to monitor the voltage drop across the resistor connected to the lower MOSFETs' sources.

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tion, this current could rise to a value limited only by supply voltage and circuit resistance. The necessary protection is provided via the feedback loop formed by U1's Fault output, U3A, U4B, and U4D. When I_{R1} exceeds 15 A, the Fault pin of U1 conducts, triggering the 40- μ s monostable U3A. The "Q" output of U3A in turn forces the outputs of U4B and U4D to a logic low state, turning off Q1 or Q3 and turning on both Q2 and Q4. For the time during which U3A's "Q" output is high, the motor current decays through the path formed by the motor's resistance, plus the on-resistance of Q2 and Q4 in series.

In this application, turning both lower MOSFETs on is preferable to forcing all four MOSFETs off because it provides a low-resistance recirculation path for the motor current. This reduces motor and supply ripple currents, as well as MOSFET dissipation. At the end of U3A's 40- μ s timeout, the H-bridge turns on again. If the overload still exists, the current quickly builds up to the U1 "Fault" trip point again, and the 40- μ s timeout repeats. This feedback loop limits the motor current at 15 A for any combination of supply voltage and duty cycle that would otherwise cause an excess current condition. When the armature current falls below 15 A, the circuit resumes normal operation.

If there's a short across the motor terminals, the current through the H-bridge rises faster than the U1/U3A loop can regulate it. Under such conditions, the safe-operating-area limits of the MOSFETs could easily be exceeded. The necessary protection is provided by the second comparator: When the Fault comparator of U2 detects that $I_{R1} \geq 24$ A, monostable U3B is triggered. The "Q" output of U3B will then hold the Enable line of the two LT1158s low for 10 ms, resulting in a rapid shutdown and a very low duty cycle. After the 10-ms shutdown interval, U3B's "Q" output will return high, and the bridge will be reenabled. If the motor remains shorted, U3B is triggered again, causing another 10-ms shutdown. When the short is cleared, circuit operation returns to that described previously.

As a class, sign/magnitude H-

bridge systems are susceptible to MOSFET and/or motor damage if the motor velocity is accelerated rapidly, or the state of the Direction line is switched while the motor is rotating. This holds true particularly if the motor/load system experiences high inertia. The circuit shown is designed to provide protection under these conditions. The motor may be

commanded to accelerate and change direction with no precautions. In the case of deceleration, however, it's generally best to use a controlled velocity profile. If a specific application requires the ability to operate with no restrictions upon the rate of duty-cycle change, straightforward modifications can be made to the circuit to allow this. $\square$

CIRCLE 522 ADD A DIFF AMP To YOUR SCOPE

M.J. SALVATI

Flushing Communications, 150-46 35th Ave.,
Flushing, NY 11354; (718) 358-0932.

Very few oscilloscopes possess differential inputs, and only a few plug-in-type scopes offer dc comparator operation. Differential inputs are ideal for measuring small signals in the presence of high common-mode voltages. Comparator modes allow for the direct-coupled measurement of small signals riding on high dc voltages.

As is illustrated in the figure, these features can be added to one channel of any general-purpose oscilloscope. The circuit operates at unity gain in most modes, so there's no change in oscilloscope calibration. The amplifier noise level is low enough so that it doesn't degrade low-level signals, and its dynamic range is high enough to handle signals as large as ± 12 V peak.

With the Mode switch set at DIFF INF, the input resistance is nearly infinite at the inverting (INV) and non-inverting (NI) inputs. With the Mode switch set at DIFF 1M, the input resistance is the standard 1 M Ω , shunted by 47 pF (or whatever you choose). In either position, the amplifier can handle a maximum common-mode signal of ± 12 V peak.

Using 10X scope probes extends the voltage to ± 120 V peak for the 1M position. The input resistance of the NI input also is 1 M Ω in each of the dc comparator ranges. The 1-V and 10-V comparator ranges can handle dc signal levels of 0 to 1 and 0 to 10 V, respectively, at unity gain.

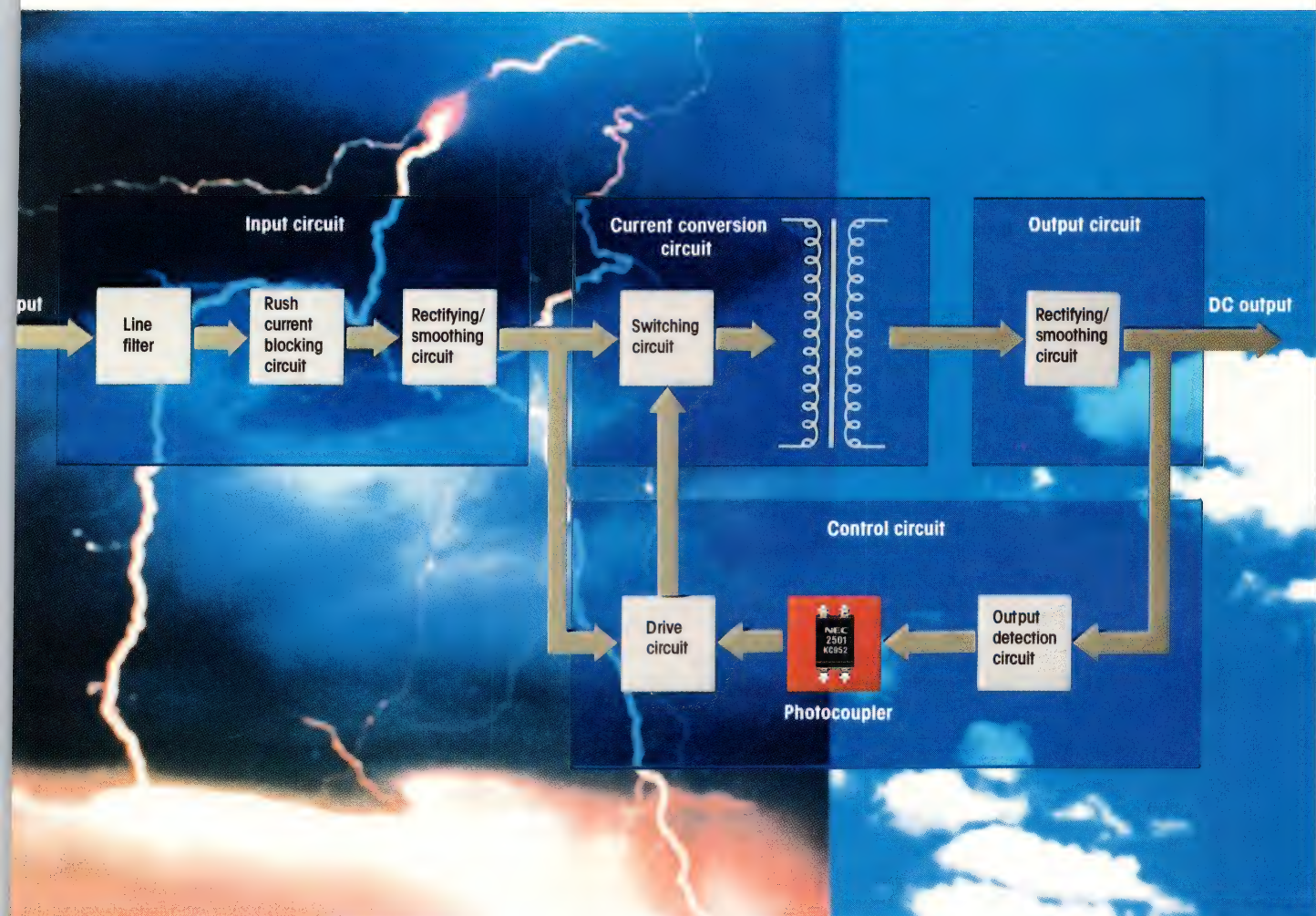
The 100-V comparator range can handle a dc signal level of up to 100 V, but at -20-dB gain (due to the 900-k/100-k resistive divider). Using a 10X scope probe extends the voltage range to the lower of 1000 V or the probe's limits.

With trimmer capacitors C_{3a} and C_{3b} , the input capacitance of the inputs can be adjusted to the same value as that of the main scope inputs, so 10X probes can be employed on the differential inputs without recompensating them. C_1 does likewise for the noninverting 100-V comparator position, and capacitor C_2 adjusts its square-wave response.

IC1 and IC2 make up a classic instrumentation amplifier. The 4700- Ω trim pot nulls the cumulative offset voltage of these op amps, while the 470- Ω trimmer pot secures the maximum dc common-mode rejection ratio. IC3 drives the input-cable shields when either of the differential modes is selected, so its important that the BNC connectors used for the NI and INV inputs are insulated.

The high-pass filter at the output of IC2 bears special notice. The value of the 1000-kHz capacitor depends on the load seen by the SIG OUT jack. The proper capacitor value (in pF) for a 3-dB roll-off at 1 MHz is approximately equal to 90 minus the total of scope input capacitance and connecting-cable capacitance. The WB (wideband) switch position shorts the 1600- Ω resistor, allowing maximum high-frequency operation.

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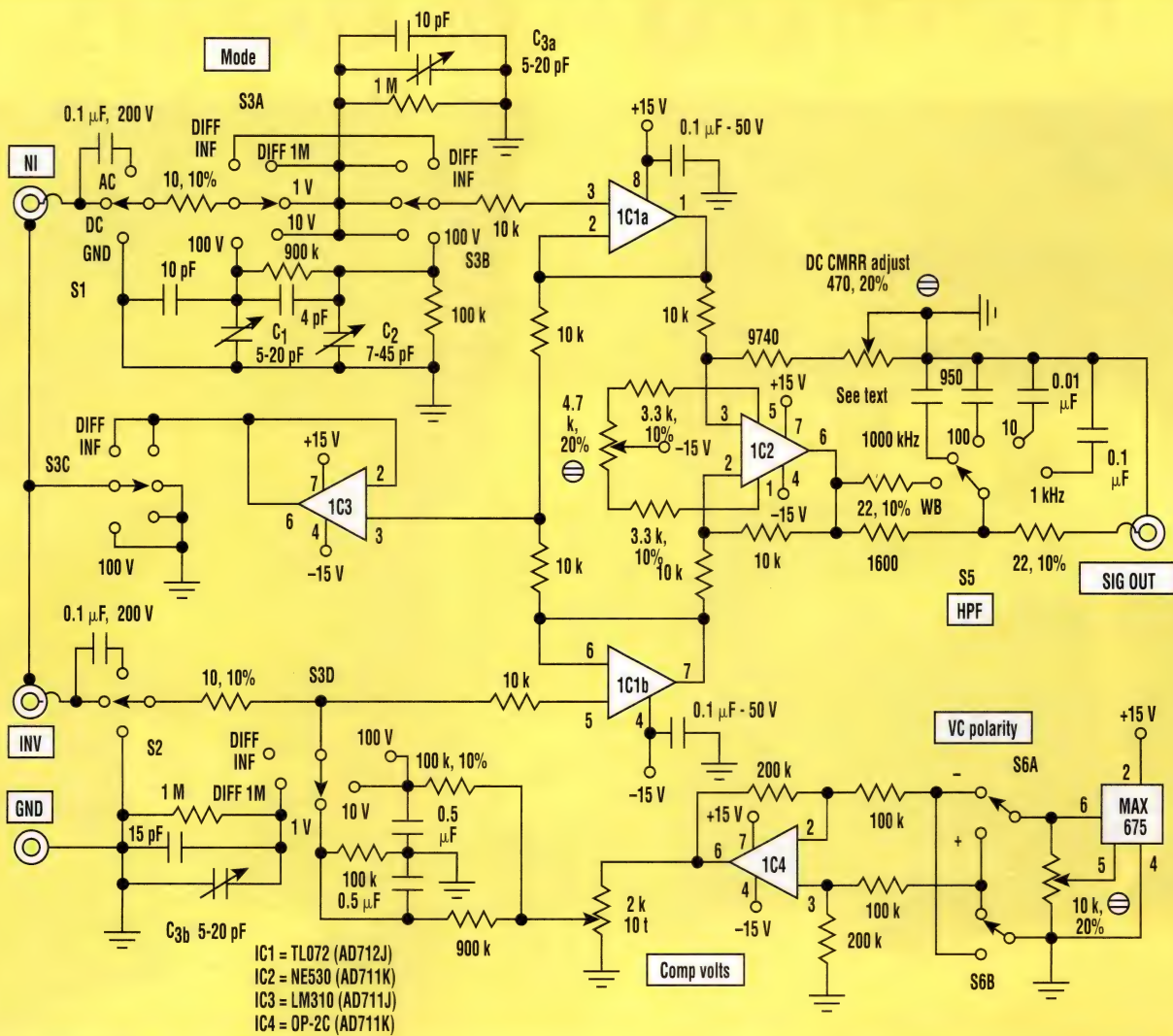
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IDEAS FOR DESIGN



DIFFERENTIAL INPUTS AND COMPARATOR MODES CAN BE ADDED to any general-purpose oscilloscope using this circuit setup. Calibration doesn't change because the circuit operates in unity gain in most modes. Amplifier noise level is low enough not to degrade low-level signals, and its dynamic range can handle signals up to ± 12 V peak. Note that all resistors are 1%, unless specified otherwise.

With 40-pF total cable and scope-input capacitance, the limit is 1.7 MHz with the original IC complement, and over 2 MHz with the suggested alternates (shown in parentheses in the figure).

The comparator voltage is initially derived from a +5-V precision reference (Maxim 675). A gain-of-two precision amplifier (IC4) boosts this to either +10 or -10 V, depending on whether the noninverting or inverting operation is selected with the VC POLARITY switch (S6). The turn-counting dial on the precision ten-turn pot indicates the exact comparison voltage selected. The full comparator voltage is applied to the in-

verting input of the instrumentation amplifier for the 10-V and 100-V comparator ranges, and is divided by ten for the 1-V comparator range. In each case, noise is filtered by a 0.5- μ F capacitor, which also ac-grounds the inverting input. $\square$

IFD WINNER

IFD Winner for June 13, 1994

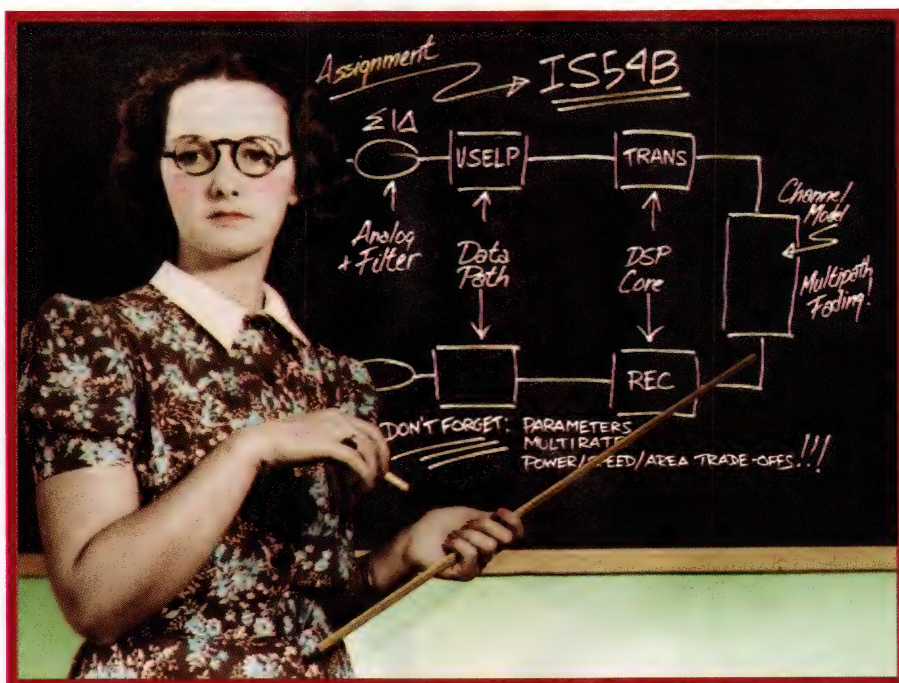
Patrick H. Conway, 28361 Plainfield Drive, Rancho Palos Verdes, CA 90274. His idea: *"Attenuator Design Equations."*

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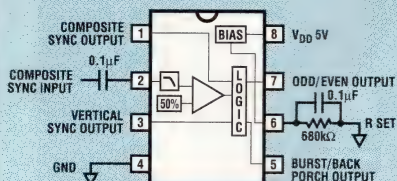
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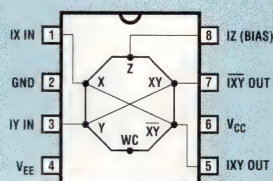
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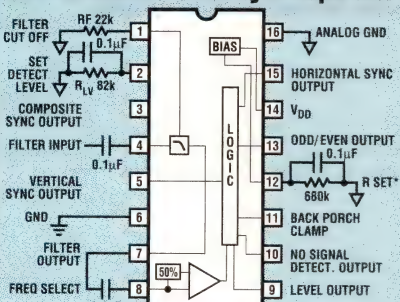
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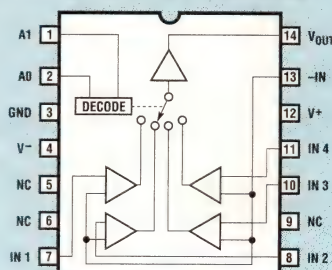
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*Note: R SET must be a 1% resistor

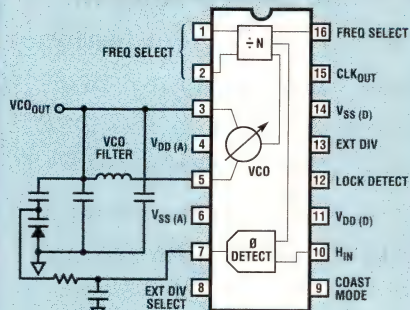
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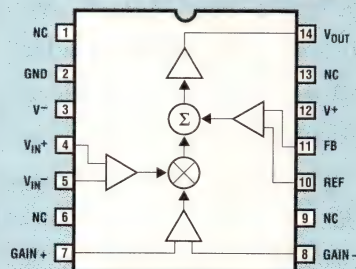
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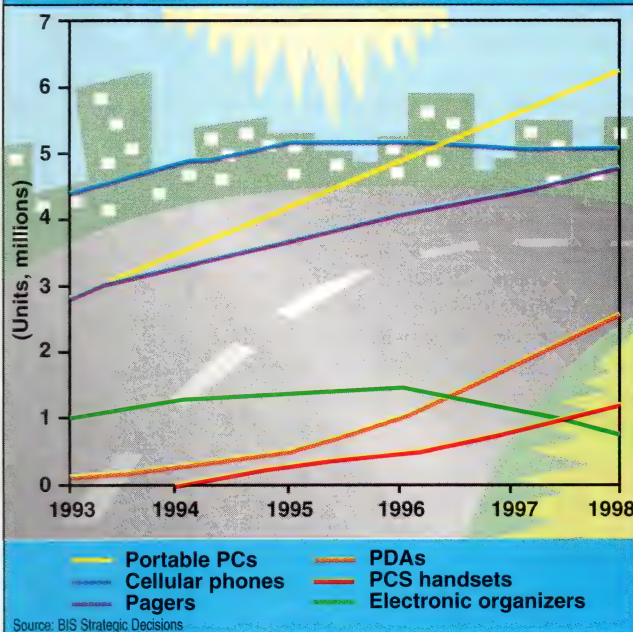
EDITED BY SHERRIE VAN TYLE

MARKET FACTS

The number of mobile computing and communication devices is growing dramatically, as shown in BIS Strategic Decisions' recent study, *Mobile Professionals in Focus: Who They Are and How They Work*. One reason is the increasing number of business trips by workers—in 1980 U. S. workers went on 97 million business trips; by 1991, that had risen to 153 million trips, according to the U. S. Travel Data Center. Last year, 11.2 mobile devices were sold in the U. S.; by 1998 sales of these units are expected to nearly double, amounting to 20.9 million devices shipped, according to the Norwell, Mass., market researchers.

Portable computers, an increasingly important part of the market, are expected to grow from the third-most-sold device last year—2.8 million units—to the best-selling device by 1997 (6.3 million). The market researchers also predict that sales of electronic organizers and personal digital assistants (PDAs) will climb from 1.1 million units in 1993 to 3.4 million units in 1994. Yet organizers won't cannibalize sales of portable PCs, the study explains, because portable PCs serve computing needs when professionals are traveling away from the office. PDAs and organizers help with local mobility needs—that is, the increasing amount of time that workers are away from their desk but working elsewhere in the building or business complex.

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Fujitsu Microelectronics Inc., which supplies electromechanical relays, connectors, keyboards, thermal printers, and flat-panel displays, has been awarded ISO 9001 at its Suzaka, Japan facility and ISO 9002 for Fujitsu's Akashi Research & Manufacturing facility, where monochrome and color AC-memory plasma displays are produced. Contact Fujitsu Microelectronics Inc., Electronic Components Div., 3545 North First St., San Jose, CA 95134-1804; (408) 922-9000; fax-428-0640. **BN** CIRCLE 464

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K M E T ' S K O R N E R

...Perspectives on Time-to-Market

BY RON KMETOVICZ

President, Time to Market Associates Inc.
P. O. Box 1070, 100 Prickly Pear Rd., Verdi, NV 89439; (702) 345-1455; fax (702) 345-0804



Clear goal: Make break-even time equal to, or even a bit faster than, that of the competition. Refer to the illustration in the last column [*Electronic Design*, Aug. 22, p. 106] to track this discussion. Because you know the value of time and use it to guide investment decisions; introduce new products as a sequence over time; follow a new product development process based on "speed profile" principles; effectively apply duration computation methods; and manage new product efforts using a database—you get your new product to market in one unit of time and consume one unit of investment.

Your competitor, on the other hand, performs marginally on some or all of the points that I've just mentioned. You see this in the competition's consumption rate of new product development money. They spend less initially. Because the value of time is not known, preservation of capital dominates investment decisions—saving some money becomes far more important than buying time. The lack of concentration on time results in continued reduced investment at low staff levels until your product arrives on the market ($t = 0$). Once your competition sees your product, they adjust the definition of their effort and absorb a significant time set back.

Because they do not follow the "speed profile" and do not compute duration, spending continues at the same rate. Maintenance of the spending rate implies keeping staff size the same. As a consequence, your competitor, because of the definition change resulting from the introduction of your product, piles more work on an already overloaded development team. The team works long and hard to get their product to market.

The team members take longer—about 9 months—spend more money—about 50%—and then introduce a competitive product. This one might even be a bit better than yours.

Now shift attention to the profit curves. Your profits rise steadily during the period where you have no competition and continues to rise even after the competition's product appears. You got to market first with a good product and reap the rewards. You break-even in 2.5 units of time. Meanwhile, your competitor struggles.

His/her sales do not rise as quickly. This results in lower manufacturing volumes and quite possibly hides unit costs. And because the market they enter already relies on your product, the competition spends more on marketing and sales to overcome the existing market barriers.

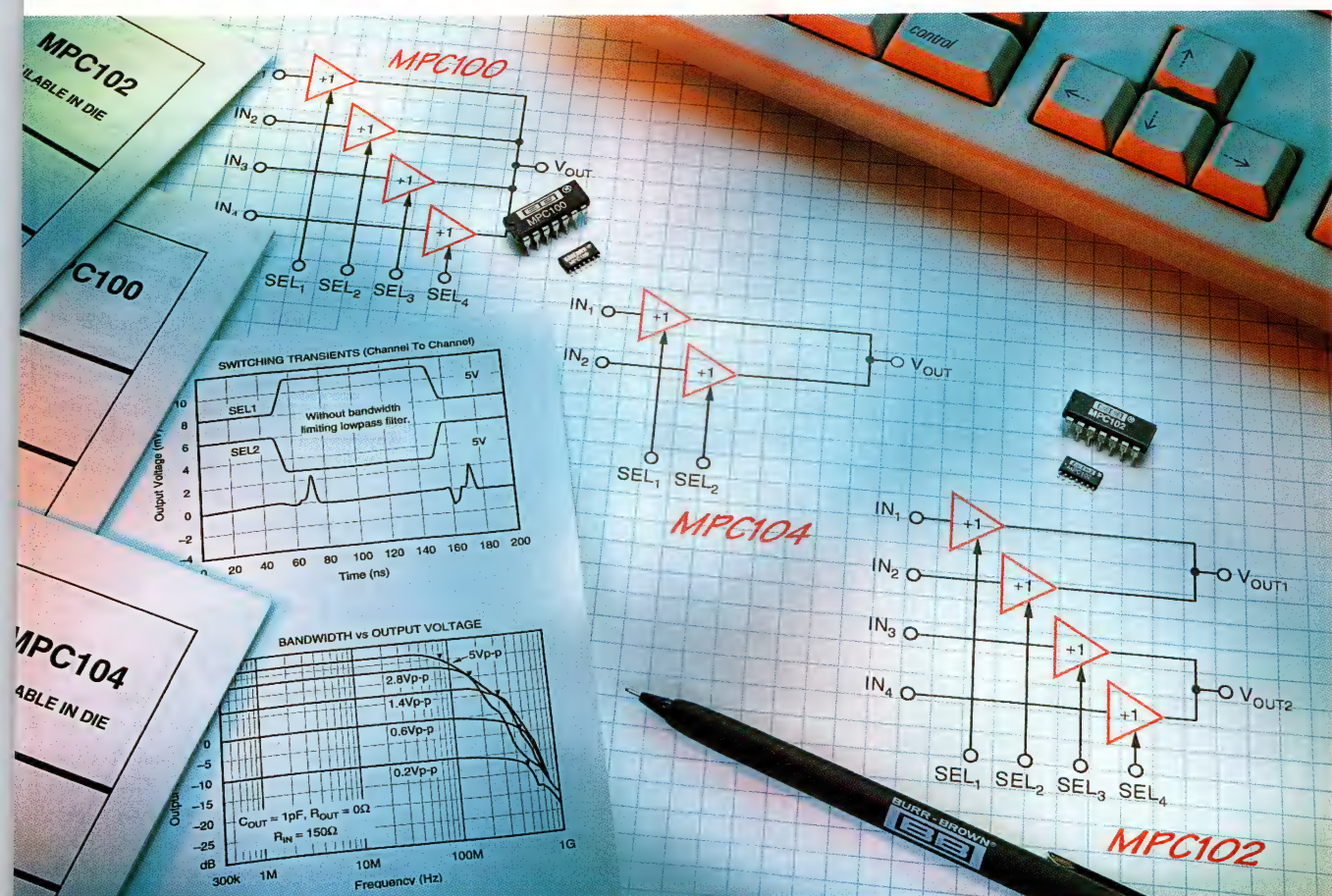
These factors all contribute to the generation of fewer profit dollars by the competition. As such, the profit curve rises with a significantly reduced slope over that of the early market entrant. The ultimate result is that it takes your competitor more than four time units to break even.

Looking at the end points of each curve and forming some simple profit to investment ratios shows the real business winner. After four years, you returned 4.5 profit dollars after investing 1.5 investment dollars—a ratio of 3:1. Meanwhile, your competitor spent 2.3 investment dollars to return 2.8 profit dollars—a ratio of 1.2:1. Who wins?

Go forth and make a few BET graphs that show your position with respect to the competition on a few products you've done in the past. Take what you learn from this exercise and apply it to products currently under development. Use the forecasts based on quality BET information to guide your behavior.

Ron Kmetovitz's The One-Minute Time to Market Self Assessment, which identifies five key behavioral patterns exhibited by fast-moving new product development organizations, is available free to the readers of Electronic Design by contacting Time to Market at P. O. Box 1070, 100 Prickly Pear Rd., Verdi, NV 89439; (702) 345-1455; fax (702) 345-0804.

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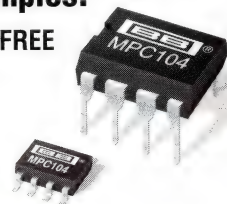
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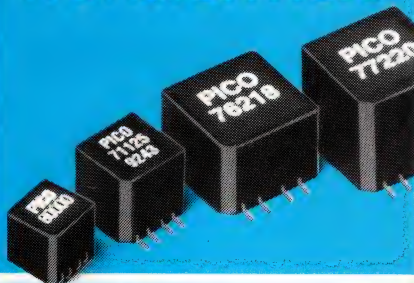
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QUICKLOOK

M Y V I E W

...Working together

BY FRANK J. BURGE

Director of Market Development for Electronic Design



We have to do a better job of working together. We must work together to develop products that customers value, to bring products to market faster, to create an environment that brings out the best in people, and to build customer confidence in everything we do. But working together doesn't come naturally to most people or companies. When I travel, for example, I notice that some flight crews seem happier and more eager to be helpful than others.

My guess is that one or two members of the crew inspire the rest. Or a few grouches poison the rest. Or maybe it's training. On a recent flight from Chicago to San Francisco, we hit some rather turbulent air and I was in the rear of the aircraft, trapped by a serving cart. I had a badly sprained ankle so I was anxious to get back to my seat since I was being tossed about. When I asked the flight attendant to let me through, she pretty much ordered me back to the rear of the plane until she was finished picking up trays. Rather than become obnoxious, I moved back to the rear and waited for her to finish. It's a funny thing, but most of the attendants on that flight were grouchy, and I got the feeling that they wished they were somewhere else.

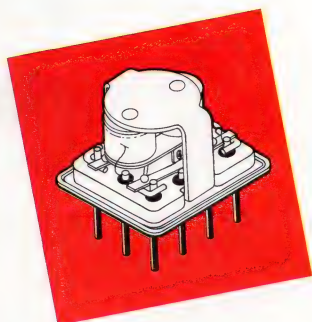
This reminds me of a talk I had recently with our daughter Frances, who is a chef—that is, after attending the Culinary Institute, she is working her way up the kitchen ladder. When one has an outstanding meal

at a fine restaurant, the chef gets the applause, but if it weren't for the dishwasher, line cook, sous chef, garde-manger, prep cook, line cook, pastry chef, servers, and the rest of the crew, nothing much would happen. Frances described the great feeling that comes with working in a kitchen where everyone is working together. It's like an orchestra playing a symphony; everyone basks in the applause.

The way a kitchen operates is not unlike the way many electronics companies work. Some chefs operate on the principal of intimidation. They bark at the kitchen staff and berate them into line. And Frances has worked for two such chefs, one with an international reputation. At first, the barking gets results because a great chef won't permit the customer to be served anything but perfection—anything less would risk his four- or five-star rating. Turning out a world-class meal should be fun but the barker can't hold his team together because of the environment he creates. The tension in the kitchen tears at the human spirit; people burn out and move on.

Other chefs seem to have a knack for building a kitchen staff and then inspiring them to do great work. The chef and sous chef create an environment in which working together is a joy, an environment in which everyone on the staff has an opportunity to express their ideas about improving the dining experience. In busy times, there may be conflict in the kitchen. People get pushed out of the way and tempers flare. But the job gets done. And when the day is over, and the staff cleans up for tomorrow, the conflicts of the evening are set aside amid the exhilaration that "we did great work tonight." I wonder how many companies benchmark their team-building performance against the workings of a world-class kitchen. It might be an eye-opening experience. And the worst that can happen is a great dining experience. Working together should be fun.

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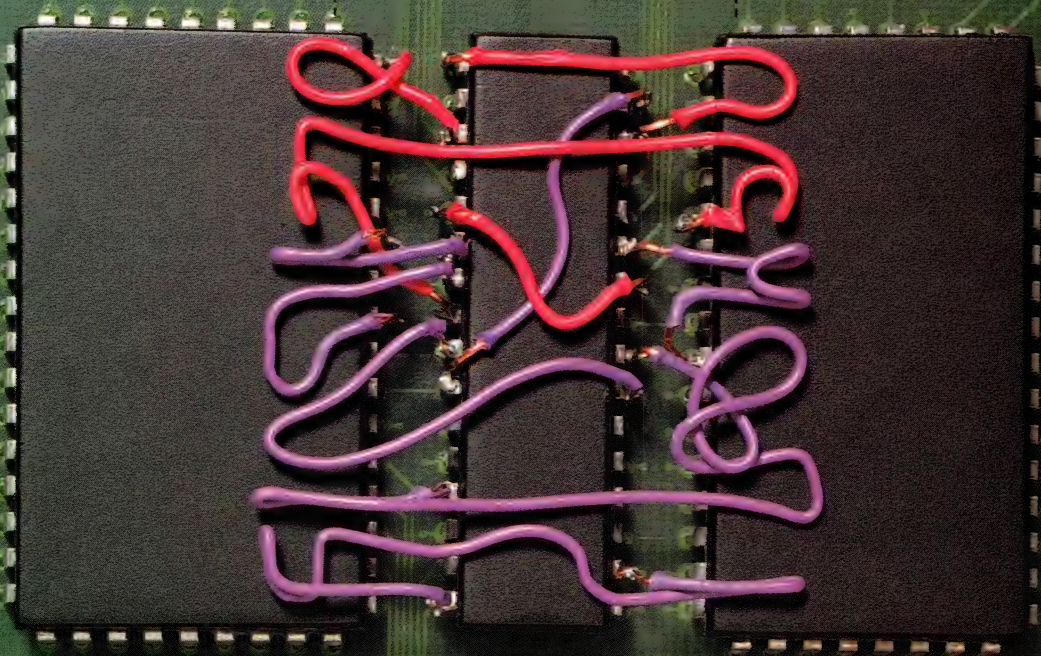
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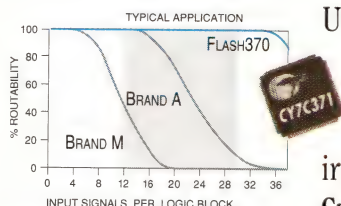
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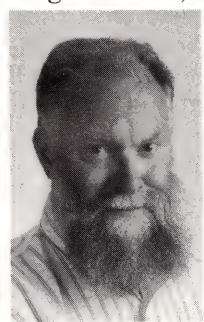
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 **CYPRESS**

WHAT'S ALL THIS RENDEZVOUS STUFF, ANYHOW?

A few months ago, I proposed that a bunch of us survivors from Philbrick Researches get together for a reunion at the Hilton, across from the old Philbrick plant in Dedham, Mass. Many of the guys showed up at 5 P.M. Others straggled into the bar at 6 P.M., and others yet at 6:30. Some only arrived at 7. But we had a pretty good get-together, about three dozen people in all.

One guy, Tom, showed up around 5, went to the bar, ordered a beer, and watched everybody coming in the door. He did not recognize anybody. He got nervous, and began to wonder



BOB PEASE

OBTAINED A BSEE FROM MIT IN 1961 AND IS STAFF SCIENTIST AT NATIONAL SEMICONDUCTOR CORP., SANTA CLARA, CALIF.

if he was in the right place. He called Joe, the Cruise Director, but Joe was not at home, so he left a message on Joe's phone machine. Well, Joe got the message from Tom that "I am at the Hilton—now, where the heck is everybody?" But while Tom said he was at the Hilton, he did not say any more details of where he was, exactly. At the end of the evening, we mourned the fact that our friend

Tom had not arrived. Why??

Weeks later, we completed our post-mortem analysis of this situation. Tom provided proof that he had shown up at 5:01 P.M., as the receipt for his drink confirmed it. Heck, Tom could prove that he was there, and we could not

prove that we were there! The nominal time for the meeting was supposed to be 5 P.M., but I was tied up in business meetings, and arrived about 6:10. Joe, the Cruise Director, the guy in charge of coordinating the meeting, got out of work late and arrived at the meeting by about 6:40. But Tom got nervous by 6:05 P.M., and left to check out other possibilities—other locations.

Maybe we misled him, maybe we told him the wrong place to go? No, he was actually in the right place. But Tom had neglected to bring the Official Invitation (as published in *Electronic Design*, March 21, 1994, p. 116) with him.

Thus begins the comedy of errors. He could not cancel out his concerns that perhaps he was in the wrong place. And there was no real person Tom could call to ask, "OK, exactly where is the right place?"

NOW, the real culprit in this quandary is the telephone company. Apparently, most telephone companies have decided that any public phone should not have a posted number, and that you should not be able to call back to the pay phone. This is supposedly to hinder drug dealers—that's the story I heard anyway. If Tom had been able to say, "Call me back at 617-333-3333," we would have been able to tie up the loose ends easily. But the telephone company is forbidding us to use that solution. Not very helpful.

The other half of the conspiracy is that the Hilton apparently has two bars. Tom assumed correctly that we would be... in the bar. Heck, we weren't going to hire a meeting room. It would be absurd to hire a hall, when the lounge area was exactly the right place for us to meet and mingle and sip. But, apparently this Hilton had two bars. The one bar had a clear view

of the front door, so Tom could see anybody he recognized coming in the front door. But, some of us had already snuck into the other bar. That did not help much. And we, not realizing there were two bars, were remiss in checking around the lobby to see if there was another bar.

Every family has its own stories about a Rendezvous that didn't work. "We told Jimmy to wait by the Santa Claus in the store. How could *we* know that the store had *two* Santas?" It's funny *afterwards*, but not funny at the time. When we first moved to San Francisco, we volunteered to drive one of our new neighbor's kids to school. We sat and waited for the kid at the corner of Miramar and Eastwood for about 10 minutes—until we began to realize that there are *two* places where Miramar intersects Eastwood. And, sure enough, Wendell was that little *dot* down there at the *other* corner of Miramar and Eastwood.

When you go on a hike—or a canoe trip—it's surprisingly easy for one person to get separated from the rest of the group. Okay, you come out of the woods, and if the trip leader has not forewarned everybody the right place to call to reestablish connections, then you can waste lots of time trying to find each other, with each one not knowing where the other party is.

So, how do we do a Rendezvous correctly? The first thing is to have a telephone contact with a real person who can take reasonable messages and pass them along. For example, if I'm in the northeast corner of Nowhere and I suspect that my wife is searching for me in the SE corner or the SW corner of Nowhere, then we have arranged that we should each call my mother, and she can pass along the message where to go. She can take the message from the first person who calls and give it to the second person who calls. Therefore, if your mother is likely to be at home, or whoever, then agree with your wife and kids that he or she is the person you should always call. OR, if you have a cellular phone, let them call *you*. That would have helped us in Dedham, but nobody had a cellular phone. If it is a really serious situation, you could call the police and

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PEASE PORRIDGE

tell them about the lost-person problem. But if the second person calls in to the *wrong policeman*, it may still take quite a while to get connected.

Do you have a phone machine, or a voice-mail system, where others can call and leave a message and then you can call in to receive your own messages? That may be a good possibility for linkup. It's one of the better ones. That's because the first logical solution—"Here's where I am, please call me back"—has been sabotaged by the telephone company, which will not let us call back to a public telephone... Anyhow, if you have any ideas on this, please let me know. *YOUR* family may have figured out some ideas better than ours.

All for now. / Comments invited!
RAP / Robert A. Pease / Engineer

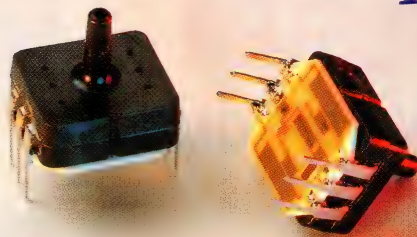
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p.s. What does *Rendezvous* really mean, anyhow? Everybody understands that it means some kind of get-together. But, how does that French phrase get translated?? Very simple: *Rendez* = present, and *Vous* = you. Thus, "Present yourself"—this represents an agreement that we will all "present ourselves" at the agreed-upon time and place. Ain't etymology interesting? I think so... what's all this etymology stuff, anyhow?

p.p.s. If you're a strong, fast hiker, you'd probably enjoy hiking across England from the west coast (from St. Bees on the Irish Sea) to Robin Hood's Bay on the North Sea. It's only 192 miles on the "Wainwright route," wending through the handsome, rugged countryside of the Lake District, the Yorkshire Dales, and the North York Moors. You can take all the time in the world—or you can do it in 12 days as we did, hiking with Avalon Trekking of Perth, Scotland. From the U.S.A., call 011-44-738-624194 for a brochure. Or, ask Wilderness Travel, Berkeley, Calif., at 510-548-0420 for their brochure, as they hike about 8 to 12 miles per day.

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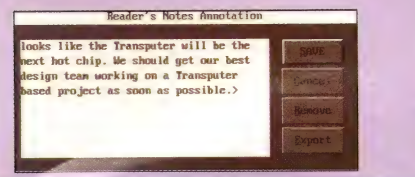
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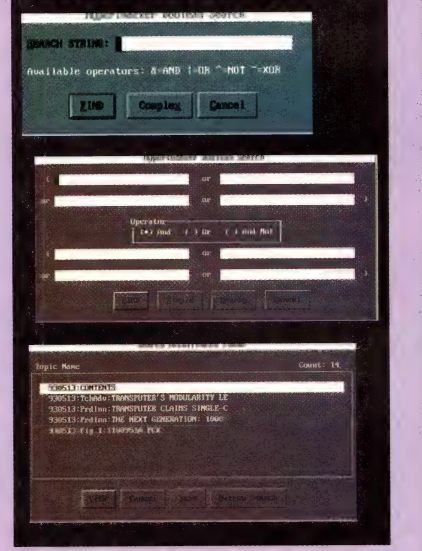
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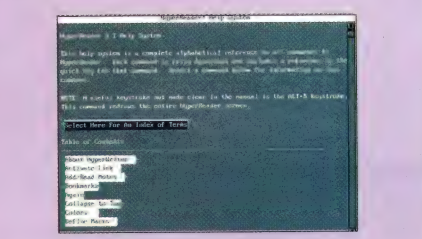


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Pulse Loading: A "Hot" Issue For Resistors

A modeling technique helps predict thermal breakdowns, improving end-product reliability.

BY PIET HUISSOON

Philips Components, Fixed Resistor Development Dept., Bredeweg 10, 6042GG Roermond, The Netherlands; (31) 4750 85253.

Most designers know that modern electronic circuits are very sensitive to transients. Much effort has been made by circuit engineers to protect semiconductors from these potentially destructive pulses, but other components often are neglected in the process. For their part, resistors are frequently located in areas likely to experience transients, such as adjacent to power supplies. Their thermal behavior, and especially their response to pulse loading, is a crucial issue that gains in importance as resistors become more miniaturized.

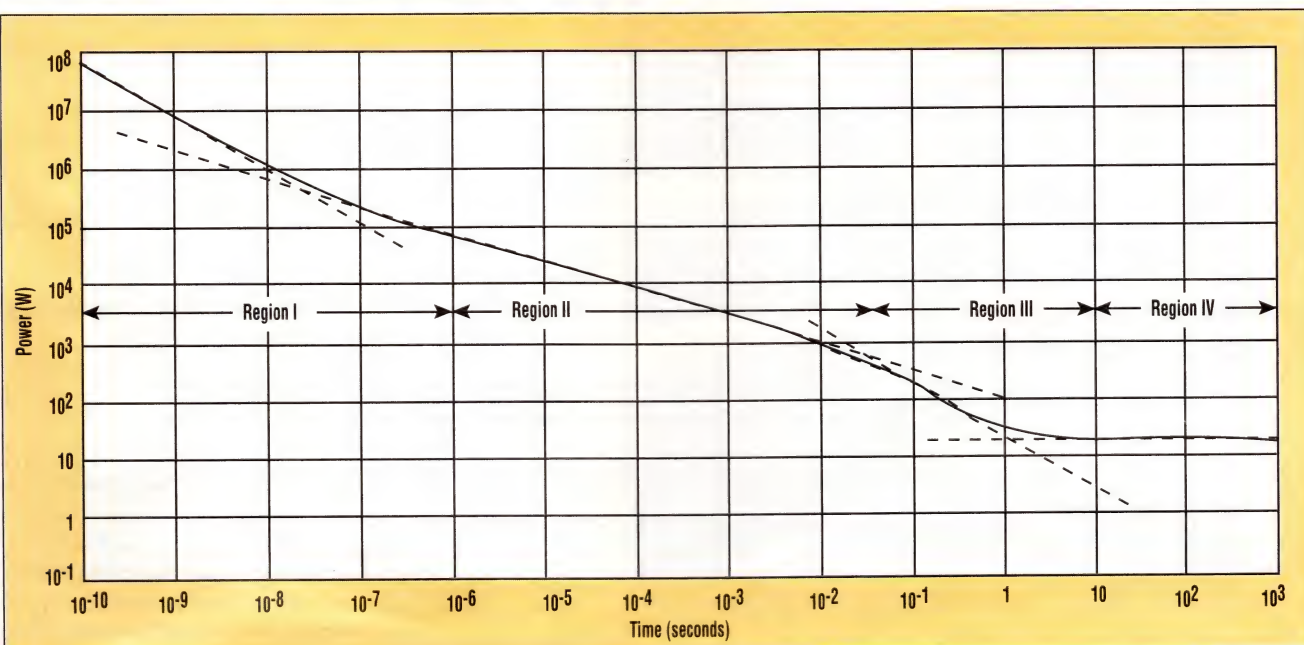
Today's compact, cylindrical resistors have ceramic bodies

with a high aluminum content. Heat is therefore more easily conducted to the ends of the resistor body than in older designs, resulting in less pronounced hot spots and a more uniform temperature distribution. Therefore, the resistor's power rating can be increased for a given hot-spot temperature and hence a given stability. While this has advantages for continuous loading, it does leave less in reserve to contend with transients. It also means that it's more important than ever to be able to clearly predict how a particular resistor will behave under pulse loading. With this in mind, Philips Components

closely studied the thermal behavior of modern resistors, specifically to make reliable information available to circuit designers and, where necessary, to provide them with effective design-in support.

A pulse load is defined as a pulse of short duration with a power greater than the continuous allowable power rating of the resistor. Such pulses can be one-time events or can occur repeatedly. The pulse-load capability of a resistor involves being able to withstand repeated pulse loads of equal magnitude over a specified period without failure and with a resistance drift at the end of the applied pulses less

1. The four breakdown regions of a cylindrical resistor show how the devices behave under pulse loads of varying duration.



RESISTOR PULSE LOADING

than a specified amount ($\Delta R/R$ typically $< 1\%$). The range of pulse durations, t_i , encountered in applications is very wide and can usefully be divided into four regions (Fig. 1).

• **Region I:** All heat remains in the resistive layer because over the short time of the pulse, no heat penetrates the lacquer or ceramic. This is typical of pulses caused by lightning and ESD.

• **Region II:** According to the theory of heat conduction, $P_{peak} \propto 1/(t_i)^{0.5}$ for a cylinder whose surface is heated from the outside, without heat transport along the axes and without heat loss due to convection and radiation. This is typical of discharge pulses.

• **Region III:** As t_i increases from 10^{-2} seconds to around 1 second, heat-penetration depth increases from 0.1 mm to 1 mm. The relationship between P_{peak} then gradually changes from a $1/(t_i)^{0.5}$ proportionality to a $1/t_i$ proportionality. This is because at full axial penetration, the resistor behaves like a mass heated at constant power. At the same time, however, heat penetration in the axial direction means that the temperature rise will be lower than predicted. Hence, P_{peak}

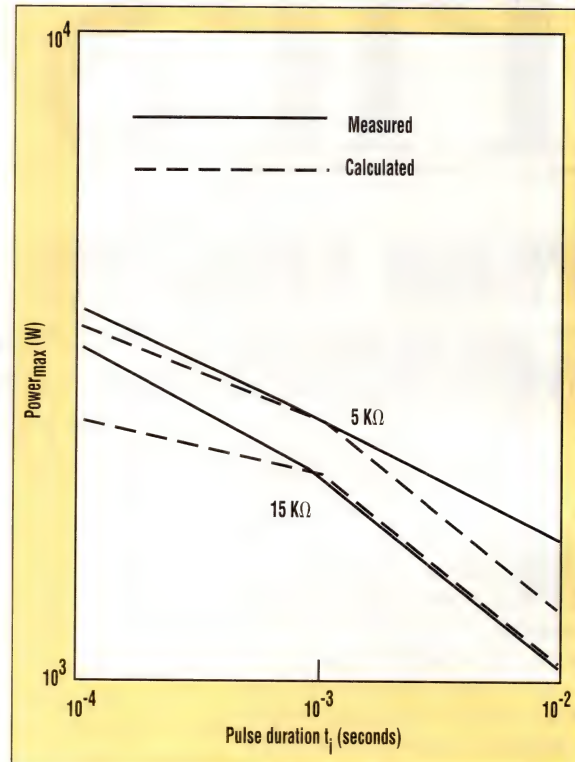
will be higher.

• **Region IV:** Normal load conditions.

The theory of film-resistor pulse loading assumes that a resistor breaks down during a pulse when the resistive layer reaches a certain temperature. This temperature might, for example, be the resistive material's melting point. The pulse load at which the resistor breaks down can therefore be found by first calculating the temperature rise of the resistive layer as a function of the power in the pulse. Then, the point at which this temperature exceeds an assumed "breakdown" temperature in the layer is found.

Past attempts to predict breakdown behavior have been unsatisfactory because they assumed an ideal resistive layer. Philips, however, developed a new hot-spot model that gives far more accurate predictions. It does so by accounting for intrinsic heterogeneities in the resistive layer (which can lead to hot spots) and in the field strength at the laser-trimmed end points of the resistive material.

While developing the hot-spot model on which the equivalent-circuit program is based,



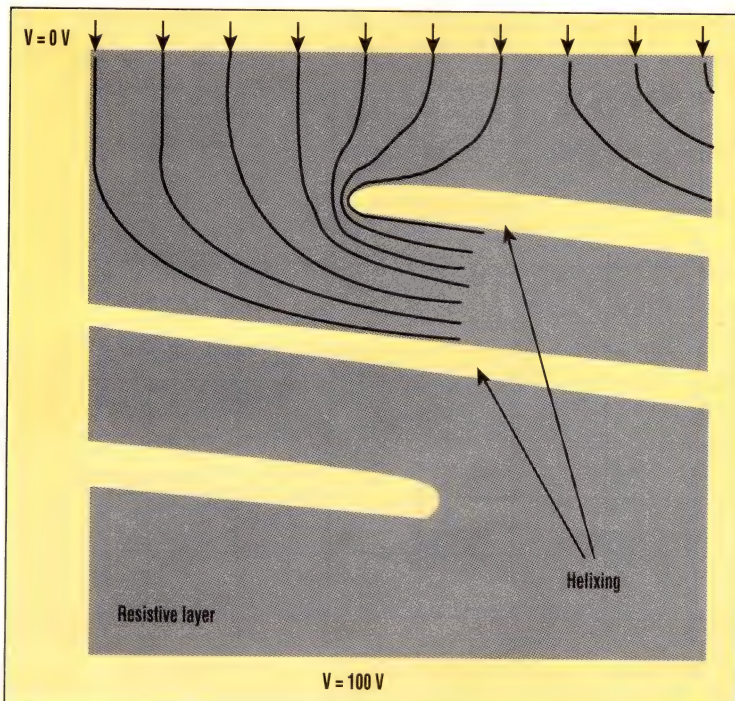
3. For conventional NiCr film resistors, Philips's model agrees with the measured behavior, and the pulse-load-limitation calculations using the model agree with those of IEC/DIN.

two assumptions were made. It's assumed that the resistive material has intrinsic heterogeneities that give rise to a given hot-spot distribution. It also is assumed that the field strength at the beginning and end of the helix exhibits heterogeneities (Fig. 2).

Using this model, an equivalent-circuit program was developed that calculates the breakdown pulse loads and allowed pulse loads for cylindrical resistors as functions of the following parameters:

- Thermal properties of the ceramic
- Body diameter
- Properties of the resistive layer
- Layer thickness
- Length of laser cut
- Radius of the end of the laser groove
- Surface area of the groove
- Pulse duration
- Pulse repetition time

Measurements using pulse-test equipment with resistors of differing dimensions and ceramics have amply verified these calculations. The equipment delivers a rectangular pulse according to IEC specifications. To get a good fit between the calculated



2. While developing the hot-spot model (on which the equivalent-circuit program is based), it was assumed that the resistive material has intrinsic inhomogeneities that give rise to a given hot-spot distribution. The diagram shows the current-density deviation of a helical resistive layer.

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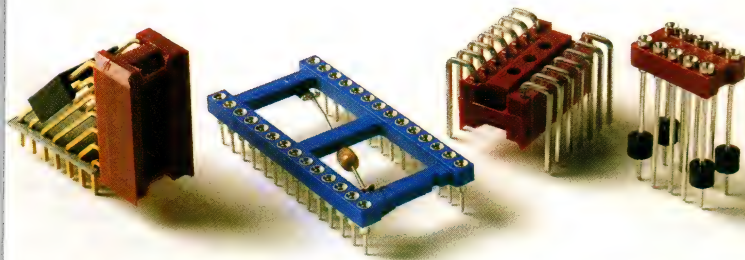
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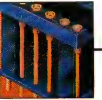
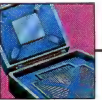
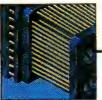
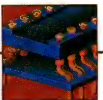
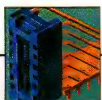
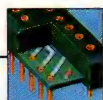
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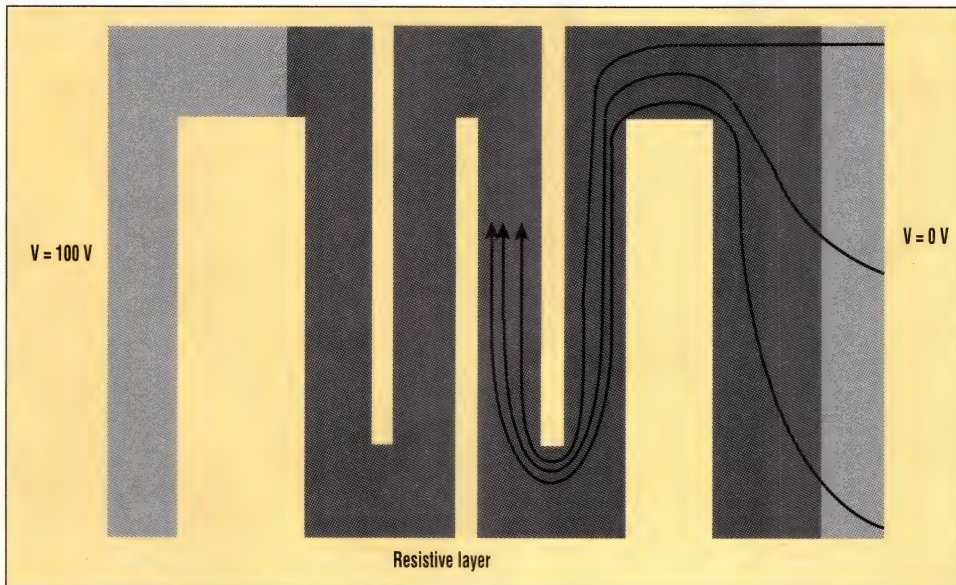
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4. The meander pattern often used to increase resistance in thin-film chip resistors can result in relatively high current densities. The meander's effect on pulse-load behavior, however, is controllable.

and measured pulse loads ($\Delta R < 1\%$) for single and repetitive pulses, a breakdown temperature of 900°C was assumed for a single pulse and 300°C for repetitive pulses. These seem to be suitable values for all film resistors because they use nickel chromium (NiCr) films.

For conventional NiCr film resistors, this model closely matches the measured behavior, and the pulse-load-limitation calculations using the model agree well with those given by IEC/DIN (Fig. 3). Philips' published pulse ratings for its cylindrical resistors now are based on this model. Moreover, the published ratings relate specifically to minimum performance levels within a resistor family. Therefore, designers can feel confident that the performance of an individual resistor in a family will be at least as good as, and most likely better than, these ratings.

Currently, no theoretical model is available for calculating the pulse-load ratings of thick-film resistors. Because the thick-film structure leads to heterogeneous current flow, the behavior of a thick-film resistor at overload differs considerably from that of a thin-film type. Curves published for thick-film chip resistors must therefore be determined from measurement, so it's more difficult to predict

the behavior of these resistors under pulse-load conditions.

Nevertheless, it's possible to consider some effects of pulse-load behavior with regard to thick-film resistors. As with conventional resistors, heat energy concentrates at the end of the laser groove, which can affect pulse-load behavior. What's more, the type of laser cut—whether L-cut or single cut—is found to influence this behavior. The L-cut gives a lower heat flux, leading to higher pulse-

load ratings. In general, an untrimmed resistor can accept a pulse load three or four times as great as a trimmed resistor. Philips, incidentally, includes in its offerings the untrimmed RC02TR resistor for circuits in which good pulse-load rating is important.

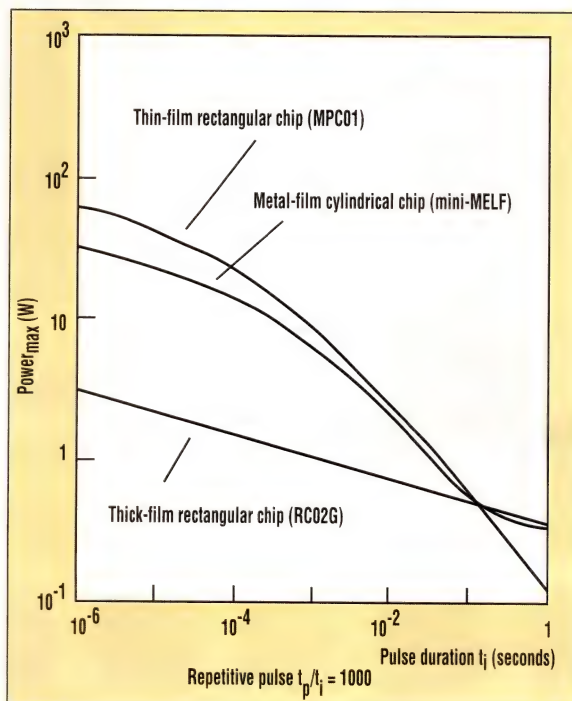
To sum up, the pulse-load rating of thick-film resistors is generally lower than that of cylindrical resistors. But as with cylindrical resistors, the ratings quoted by Philips always relate to minimum performance levels. Thus, the performance of any individual resistor is likely to be better.

A thin-film chip resistor consists of a metal-film layer sputtered onto a ceramic plate with high thermal conductivity. For higher resistances, a meander pattern is often used. Because relatively high current densities can occur in the curves of the meander, it's reasonable to assume that such a structure will affect pulse-load behavior (Fig. 4). However, this problem is not as great as it seems. Looking at the relationship between current density and curve radius, one gets:

$$\frac{J_{\max}}{J_o} = \frac{R_2}{R_1 - 1} / \ln\left(\frac{R_1}{R_2}\right)$$

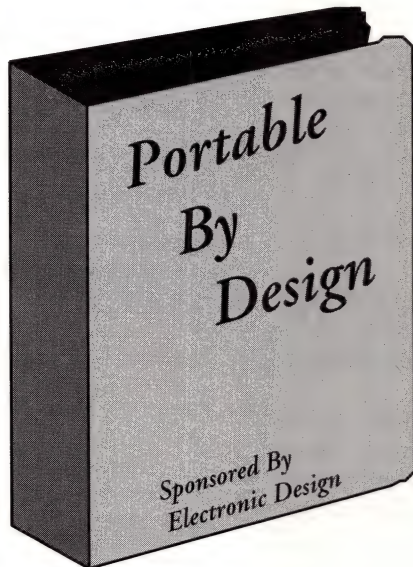
where $J_{\max}$ is the current density in the curved part of the circuit

5. The published graphs for Philips' MPC01 thin-film chip resistor are based on measured values. These do, however, reveal the value of the actions already taken to improve the pulse-load behavior of this chip. The device's pulse-load capability is up to 10 times that of 1206-style thick-film resistors.



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pattern; J_o is the current density in the linear part of the pattern; R_1 is the radius of the meander's inner curve; and R_2 is the radius of the meander's outer curve. So with an appropriate choice of curve radius, it's possible to set $J_{max}/J_o = 1$ and avoid increases of current density throughout most of the meander pattern.

For the pulse-load study of thin-film resistors, the investigators at Philips used the same model and theory employed for cylindrical resistors. This includes the assumption of heterogeneities in the resistive layer and in the field strength at the laser-trimmed end points. So far, however, the correlation between measured and calculated behavior for thin-film chip resistors isn't entirely satisfactory, and work is ongoing to develop a program for reliably predicting pulse-load behavior comparable to that already developed for cy-

lindrical resistors.

Meanwhile, the published graphs for Philips' MPC01 thin-film chip resistor are based on measured values. These do, however reveal the value of the actions already taken to improve the pulse-load behavior of this chip (for example, setting $J_{max}/J_o = 1$ wherever possible in the meander pattern). We can show, for example, that the pulse-load capability of this resistor is between 3 and 10 times greater than that of 1206-style thick-film resistors. Moreover, this thin-film chip resistor's performance is even better than that of the cylindrical (mini-MELF) resistor (Fig. 5).

In general, certain conclusions can be drawn. It can be said that the pulse-loading capability of large resistors is better than that of small resistors and that thin-film SMD resistors are more effective than thick-film

types. Leaded (metal) film resistors are better than SMD resistors for this purpose.

With the trend toward miniaturization of end products and surface mounting being the primary means of assembly showing no signs of slowing down, the pulse-loading capability of resistors is likely to become an increasingly important phenomenon in the future.

Piet M. Huissoon has spent the last 5 of his 33 years at Philips as a member of the Application-Specific Resistors Group. He is primarily responsible for handling customers' application questions.

Work is ongoing to develop a program for reliably predicting pulse-load behavior.

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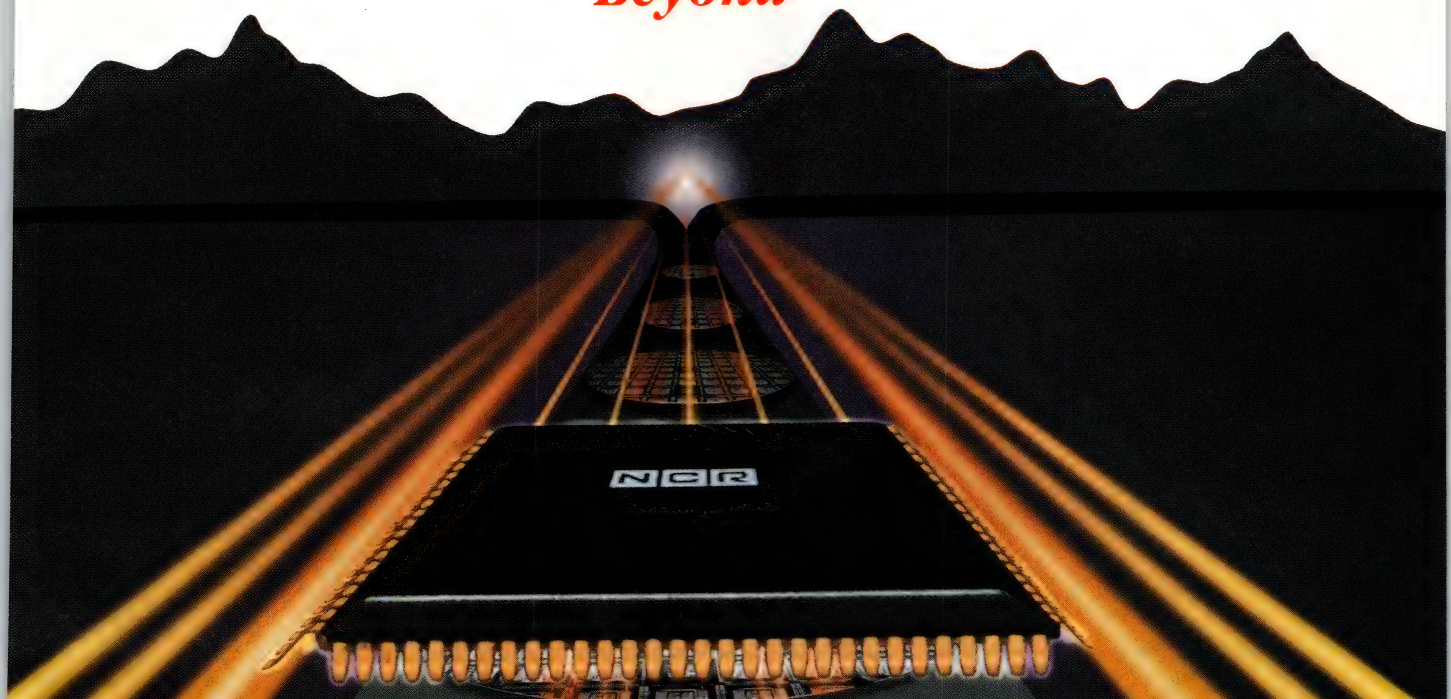
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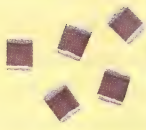
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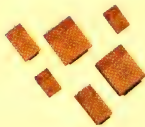


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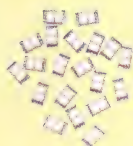
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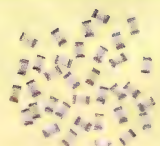
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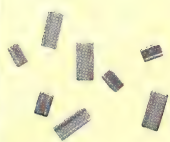
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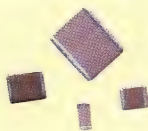
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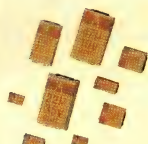
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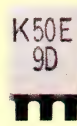


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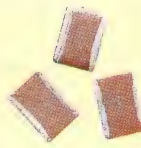
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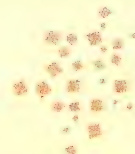
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Aerovox Aero M

20 Aberdeen Dr.
Glasgow, KY 42141
(502) 651-8301
(EA)
CIRCLE 805

Aerovox Inc.

740 Belleville Ave.
New Bedford, MA 02745
(508) 994-9661
(EA) (FP) (FY) (PF)
CIRCLE 806

American Precision Industries

Delevan/SMD
270 Quaker Rd.
East Aurora, NY 14075
(716) 652-3600
(AF) (IF) (RF) (SU)
CIRCLE 807

American Radionic Co. Inc.

AmRad Engineering
32 Hargrove Grade
Palm Coast, FL 32137
(904) 445-6000
(FY)
CIRCLE 808

Andersen Laboratories Inc.

45 Old Iron Ore Rd.
Bloomfield, CT 06002
(203) 286-9090
(VC)
CIRCLE 809

Arco Electronics Inc.

5310 Derry Ave.
Agoura Hills, CA 91301
(818) 707-6465

(CD) (CM) (ED) (FP) (MI) (CP)
(VB) (SU) (PL) (PF)
CIRCLE 810

Associated Components Technology

11576 Trask Ave.
Garden Grove, CA 92643
(714) 636-2645
(RF) (SU) (PF)
CIRCLE 811

Bliley Electric Co.

2545 W. Grandview Blvd.
Erie, PA 16508-0428
(814) 838-3571
(QC) (SC) (CY) (TC) (VC)
(CK)
CIRCLE 812

Bourns Inc.

Integrated Technologies Div.
1400 North 1000 West
Logan, UT 94321
(801) 750-7200
(AU) (CF) (CE) (TF) (TH)
(WW) (CO) (ST) (MT) (TR)
(RN) (CN)
CIRCLE 813

Bourns Inc.

Trimpot Div.
1200 Columbia Ave.
Riverside, CA 92507
(909) 781-2517
(AU) (CF) (CE) (TF) (WW)
(CO) (ST) (MT) (TR)
CIRCLE 814

CTS

Frequency Controls Div.
400 Reimann Ave.
Sandwich, IL 60548
(815) 786-8411
(MC) (QC) (SC) (CY) (TC)
(VC) (CK) (SO)
CIRCLE 815

CTS Corp.

Resistor Networks
406 Parr Rd.
Berne, IN 46711
(219) 589-3111
(TF) (RN)
CIRCLE 816

Caddock Electronics Inc.

Applied Sciences Div.
17271 N. Umpqua Hwy.
Roseburg, OR 97470
(503) 496-0700
(TF) (HR) (MO) (RN)
CIRCLE 817

California Micro Devices Corp.

215 Topaz St.
Milpitas, CA 95035
(408) 263-3214
(TH) (CH) (RN) (CP) (CN)
CIRCLE 818

Cesiwid Inc.

Globar Div.
P.O. Box 339
3425 Hyde Park Blvd.
Niagara Falls, NY 14302
(716) 278-2521
(CR)
CIRCLE 819

Champion Technologies Inc.

2553 N. Edgington St.
Franklin Park, IL 60131
(708) 451-1000
(CY) (TC) (VC) (CK) (SO)
CIRCLE 820

Clarostat Mfg. Co.

1600 W. Plano Pkwy.
Plano, TX 75075
(800) 448-2900
(CE) (WW) (CO) (ST) (MT)
(TR) (EM) (IE) (IS) (OS)
CIRCLE 821

Coilcraft Inc.

1102 Silverlake Rd.
Cary, IL 60013
(708) 639-2361
(IF) (RF) (SU) (PF)
CIRCLE 822

Coiltronics Inc.

6000 Park of Commerce Blvd.
Boca Raton, FL 33487
(407) 241-7876
(AF) (IF) (RF) (SU) (PF)
CIRCLE 823

Cornell-Dubilier

P.O. Box 128
538 Sangamo Rd.
Pickens, SC 29672
(803) 878-6311
(EA) (ED) (FL) (FP) (FY) (MI)
(CP) (SU)
CIRCLE 824

Curtis Industries

2400 S. 43rd St.
Milwaukee, WI 53219
(414) 649-4200
(PF)
CIRCLE 825

Data Display Products

445 S. Douglas St.
El Segundo, CA 90245-4630
(310) 640-0442
(LL)
CIRCLE 826

Dialight Corp.

1913 Atlantic Ave.
Manasquan, NJ 08736
(908) 223-9400
(IE) (IS) (LL) (LI)
CIRCLE 827

Durel Corp.

645 W. 24th St.
Tempe, AZ 85282
(602) 731-6201
(UV)
CIRCLE 828

EBG Inc.

3705 Trindle Rd.
Camp Hill, PA 17011-4335
(717) 737-9877
(CR) (MN) (TF) (TH) (HR)
(MO) (RN)
CIRCLE 829

ESC Electronics Corp.

534 Bergen Blvd.
Palisades Park, NJ 07650
(201) 947-0400
(AF) (IF) (RF) (SU) (PL) (PF)
CIRCLE 830

(see p. 114 for key)

(continued on p. 110)

OVENIZED OSCILLATOR BOASTS HIGH STABILITY

Performance rivaling atomic clocks is claimed for a high-performance ovenized crystal oscillator. The 260 Series oscillator offers a thermal stability of $\pm 1^{-10}$ over a temperature range of -30 to +65°C. The aging per day is better than 1^{-10} and the annual rate is 1^{-8} . Through its double-oven



technology, this oscillator also achieves outstanding supply-voltage and load-sensitivity performance of $\pm 1^{-10}$ in both cases. Standard frequencies of 5, 10, and 13 MHz are available from stock. Pricing starts at \$490 each depending on options.

Milliren Technologies Inc.

Two New Pasture Rd.

Newburyport, MA 01950

(508) 465-6064

► **CIRCLE 601**

RED-LIGHT LASER DIODE ENHANCES OPTICAL DISKS

A red-light semiconductor laser diode is designed especially for use in optical-disk systems. The TOLD9151MB diode operates at a wavelength of 685 nm and has an output power of 50 mW. The shorter wavelength and higher output compared to infrared alternatives (780 nm) significantly increases the storage capacity of optical-disk systems by producing a smaller read/write spot on the disk surface. Using a strained multi-quantum structure, the diode operates with low noise. Samples will be available during the third quarter for \$150 each.

Toshiba America

Electronic Components Inc.

9775 Toledo Way

Irvine, CA 92718

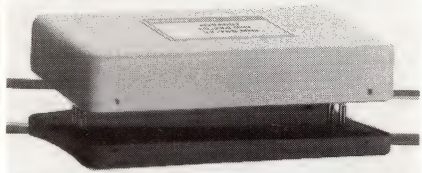
(800) 879-4963

► **CIRCLE 602**

PASSIVE COMPONENTS

▼ CRYSTAL OSCILLATOR DELIVERS DUAL TIMING

Two precise timing signals at a 3.2 constant frequency ratio are delivered without a phase-locked loop by the Type NV9A Stratum III crystal



oscillator. The unit is oven-stabilized and voltage-controlled. Typical frequencies are 10.240 MHz and 32.768 MHz. Frequency stability is maintained within 1.5×10^{-7} from zero to 70°C. Frequency deviation is $\pm 10 \times 10^{-6}$ at zero to 10 V control voltage. The unit requires supplies of +15 V dc at 30 mA and +5 V dc at 1.3 A. Call for pricing and delivery.

Bliley Electric Co.

2545 W. Grandview Blvd.
P.O. Box 3428
Erie, PA 16508
(814) 838-3571

► CIRCLE 603

▼ FILTER CAPACITORS AID SUPPLY DESIGNERS

The MPH/MPL Series of filter capacitors features an axial flame-retardant package. Type MPH comes with standard leads while type MPL comes with lug terminals. Available capacitance values range from 1 to 3 mF in voltage ratings from 100 to 400 WV dc. Ripple-current ratings are up to 30 A for the MPL and 15 A for the MPH at frequencies up to 100 kHz. Call for pricing and delivery.

Illinois Capacitor Inc.
3757 W. Touhy Ave.
Lincolnwood, IL 60645
(708) 675-1760, ext. 727

► CIRCLE 604

▼ POWER RESISTORS OFFER HIGH PRECISION

A pair of precision power resistor comes in TO-220 configuration and offers low TCR, high stability, tight tolerances, and fast response time. The models VPR 220 (a two-lead device) and VPR 221 (four-lead Kelvin connection) have power applications that include current sensing and uses as current shunts. Both handle 8 W when chassis-mounted as per MIL-R-39009 and offer TCRs of 5 ppm/°C. Tolerances to $\pm 0.01\%$ are available. Stability over load life is 0.05% maximum ΔR at full rated power at 25°C for 2000 hours. Shelf life is 25 ppm (0.0025%) per year. Call for pricing and delivery.

Vishay Resistors
63 Lincoln Hwy.
Malvern, PA 19355
(215) 640-9811

► CIRCLE 605

PASSIVE-COMPONENT MANUFACTURERS

Electrocube Inc.
1307 S. Myrtle Ave.
Monrovia, CA 91016
(818) 301-0122
(FL) (FP) (FY) (FT) (CN)
CIRCLE 831

Electronic Concepts Inc.
526 Industrial Way West
Eatontown, NJ 07724
(908) 542-7880
(FL) (FP) (FY) (FT) (FF)
CIRCLE 832

Electronic Film Capacitors Inc.
41 Interstate Lane
Waterbury, CT 06705
(203) 755-5629
(FL) (FP) (FY) (FT)
CIRCLE 833

Electronic Precision Components
BG Electronics Div.
519 S. Fifth Ave.
Mt. Vernon, NY 10550-4407
(914) 664-5591
(AF) (IF) (RF) (PL) (PF)
CIRCLE 834

ELtech
181 Gibraltar Rd.
Horsham, PA 19044
(215) 441-0404
(UV)
CIRCLE 835

Ericsson Components Inc.
403 International Pkwy.
Suite 500
Richardson, TX 75081
(214) 669-9900
(EM)
CIRCLE 836

Fox Electronics
5570 Enterprise Pkwy.

Fort Myers, FL 33905
(813) 693-0099
(MC) (SC) (CL) (CY) (TC)
(VC) (CK) (SO)
CIRCLE 837

Frequency Electronics Inc.
55 Charles Lindbergh Blvd.
Mitchel Field, NY 11553-3601
(516) 794-4500
(QC) (CL) (CY) (TC) (VC)
(CK) (SO)
CIRCLE 838

Gowanda Electronics Corp.
1 Industrial Pl.
Gowanda, NY 14070
(716) 532-2234
(IF) (RF) (SU)
CIRCLE 839

Hewlett-Packard Co.
Components Div.
370 W. Trimble Rd.
San Jose, CA 95131-1008
(800) 357-7715
(FC) (ON) (EM) (IE) (IS) (LL)
(LI) (OI)
CIRCLE 840

Hirose Electric USA
2688 Westhills Ct.
Simi Valley, CA 93065
(805) 522-7958
(ON)
CIRCLE 841

Hokuriku USA Ltd.
200 N. Northwest Hwy.
Barrington, IL 60010
(708) 382-9411
(AU) (CF) (CE) (TF) (TH)
(MO) (CH) (ST) (TR) (RN)
CIRCLE 842

Honeywell Inc.
MICRO SWITCH
11 W. Spring St.

Freeport, IL 61032
(800) 537-6945
(EM) (IE) (IS) (LL) (LI) (OI)
(PD) (PT) (PR)
CIRCLE 843

IDEA Inc.
1300-B Pioneer St.
Brea, CA 92621
(310) 697-4332
(IS) (LL) (LI) (OI) (PD) (PT)
(PR)
CIRCLE 844

Il Stanley Co. Inc.
2660 Barranca Pkwy.
Irvine, CA 92714
(714) 222-0777
(IE) (IS) (LL) (LI) (OS) (PH)
(PD) (PR)
CIRCLE 845

ITW Paktron
1205 McConville Rd.
Lynchburg, VA 24502
(804) 239-6941
(FP) (CF) (CP) (CN)
CIRCLE 846

Illinois Capacitor Inc.
3757 W. Touhy Ave.
Lincolnwood, IL 60645
(708) 675-1760
(CD) (EA) (FL) (FP) (FY)
CIRCLE 847

Inductive Components & Crystal
10555 Dale Ave.
Stanton, CA 90680
(800) 899-3420
(AF) (IF) (RF) (SU) (MC) (QC)
(SC) (CL) (CY) (TC) (VC)
(CK) (SO)
CIRCLE 848

International Mfg. Services Inc.

50 Schoolhouse Lane
Portsmouth, RI 02871-2418
(401) 683-9706
(CE) (TF) (TH) (HR) (CH)
CIRCLE 849

J.W. Miller
Div. of Bell Industries Inc.
306 E. Alondra
Gardena, CA 90248
(310) 515-1720
(IF) (RF) (SU)
CIRCLE 850

KCK America
Div. of Mitsubishi
4080 Winnetka Ave.
Rolling Meadows, IL 60008
(708) 577-0200
(CH) (CD) (CP) (SU) (PF)
CIRCLE 851

KEMET Electronics Corp.
P.O. Box 5928
Greenville, SC 29606
(803) 963-6589
(CM) (CP)
CIRCLE 852

KOA Speer Electronics Inc.
P.O. Box 547, Bolivar Dr.
Bradford, PA 16701
(814) 362-5536
(CF) (MN) (TF) (TH) (HR)
(MO) (WW) (CH) (ST) (TR)
(RN) (CP) (SU)
CIRCLE 853

Kamaya Inc.
4000 Transportation Dr.
Fort Wayne, IN 46818
(219) 489-1533
(CF) (MN) (TF) (TH) (MO)
(CH) (RN)
CIRCLE 854

LEDTRONICS Inc.
4009 Pacific Coast Hwy.

Torrance, CA 90505
(310) 534-1505
(LL) (LI)
CIRCLE XXX

Lamp Technology Inc.
1645 Sycamore Ave.
Bohemia, NY 11716
(516) 567-1800
(LL)
CIRCLE 855

MF Electronics Corp.
10 Commerce Dr.
New Rochelle, NY 10801
(914) 576-6570
(MC) (QC) (CY) (VC) (CK)
(SO)
CIRCLE 856

MTI-Milliren Technologies Inc.
Two New Pasture Rd.
Newburyport, MA 01950
(508) 465-6064
(CY) (TC) (SO)
CIRCLE 857

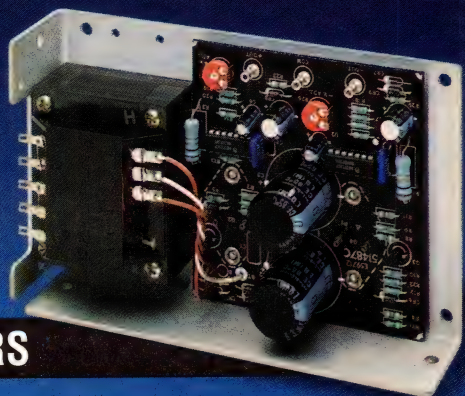
Magnetic Technology Inc.
1237 Executive Dr. East
Richardson, TX 75081
(214) 480-8585
(AF) (IF) (RF) (SU)
CIRCLE 858

Marktech International Corp.
5 Hemlock St.
Latham, NY 12110
(518) 786-6591
(FC) (ON) (EM) (IE) (LL) (LI)
(OI) (PD) (PT) (PR)
CIRCLE 859

(see p. 114 for key)
(continued on p. 112)

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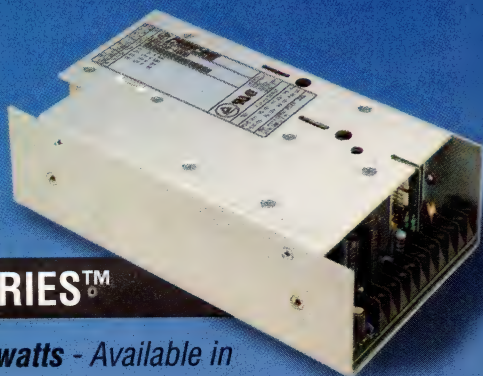
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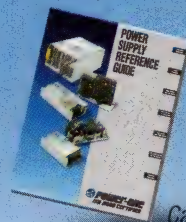


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▼ QUARTZ CRYSTALS UP FUNDAMENTALS

Computer and communications design engineers can achieve very high-frequency control over a broad temperature range with the HFX Series of quartz-crystal components. The AT-cut devices, which offer fundamental frequencies from 60 to 200 MHz, are available in miniature 2-by-5-mm or UM1/HC45 metal packages. The devices exhibit excellent aging and stability characteristics. Using the company's Tab-Mesa processing technology, the crystals are produced with overtone frequencies to 622 MHz. Frequency calibration tolerance at 25°C can be specified as ± 25 , ± 50 , or ± 100 ppm. Pricing ranges from \$3 to \$20.

SaRonix

151 Laura Lane
Palo Alto, CA 94303
(415) 856-6900

► CIRCLE 606

▼ TANTALUM-CHIP CAPS MEET SWITCHER NEEDS

Designed for use in switchmode power supplies and dc-dc converters, the Type 593D solid-tantalum chip capacitor is molded for high-volume surface mounting. The device comes in 20 different values from 10 to 220 μ F. Voltage choices include 6.3, 10, 16, 20, 25, and 35 WV dc at -55 to 85°C. Operating temperatures can be extended to 125°C with voltage derating. Low ESR and high ripple-current carrying capacity matches output filtering requirements in switchers and dc-dc converters. A typical 593D in a D case with capacitance of 100 μ F, voltage rating of 10 WV dc, and tolerance of $\pm 20\%$ with ESR of 0.1 Ω goes for \$0.589 in lots of 1000.

Sprague

678 Main St.
Sanford, ME 04073
(207) 324-4140

► CIRCLE 607

▼ LOGIC DELAY LINES IN FOUR LEAD TYPES

Compatible with FAST and Schottky T²L circuits, the PFLDL line of 3-b programmable delay lines feature stable and precise delays up to 355 ns in a 14-pin DIP package. The delay lines allow for final delay adjustment during or after installation in circuit and are available with through-hole leads or in gull-wing tacked, or J-lead SMT designs. Propagation delays are fully compensated, digitally programmable, and available in 23 delay steps with resolutions from 0.5 to 50 ns. Prices start at less than \$14 in lots of 100. Delivery is from stock to four weeks.

Engineered Components Co.

3580 Sacramento Dr.
P.O. Box 8121
San Luis Obispo, CA
93403-8121
(805) 544-3800

► CIRCLE 608

PASSIVE-COMPONENT MANUFACTURERS

McCoy, Ovenshire, Spectrum, Croven
Oak Frequency Control
P.O. Box B, 100 Watts St.
Mount Holly Springs, PA
17065
(717) 486-3411
(QC) (SC) (CL) (CY) (TC)
(VC) (CK) (SO)
CIRCLE 860

Micro Ohm Corp.
1088 Hamilton Rd.
Duarte, CA 91010
(818) 357-5377
(MN)
CIRCLE 861

Mini-Systems Inc.
Thin Film Div.
20 David Rd., P.O. Box 69
North Attleboro, MA
02761-0069
(508) 695-0203
(CR) (CE) (TF) (TH) (GL) (HR)
(CH) (RN) (CP) (CN)
CIRCLE 862

NEC Electronics Inc.
475 Ellis St., MS-MV4580
Mountain View, CA 94039
(800) 366-9782
(CM) (ED) (EM) (IE) (LL) (LI)
(OI) (PR)
CIRCLE 863

NTE Electronics Inc.
44 Farrand St.
Bloomfield, NJ 07003
(800) 631-1250
(MN) (MO) (WW) (CD) (EA)
(ED) (FP) (LL) (LI) (OI)
CIRCLE 864

North American Capacitor Co.
Mallory Div.

7545 Rockville Rd.
Indianapolis, IN 46214
(317) 273-0090
(WW) (CD) (CM) (EA) (ED)
(EW) (FL) (FP) (FY) (FT) (CP)
(VB)
CIRCLE 865

Ohmite Mfg. Co. Inc.
3601 W. Howard St.
Skokie, IL 60076
(708) 675-2600
(CC) (CF) (CR) (MN) (TF)
(GL) (HR) (WW) (ST) (RF)
CIRCLE 866

Optek Technology Inc.
1215 W. Crosby Rd.
Carrollton, TX 75006
(214) 323-2200
(EM) (IE) (IS) (LI) (OS) (OI)
(PD) (PT) (PR)
CIRCLE 867

Philips Components
2001 W. Blue Heron Blvd.
Riviera Beach, FL 33404
(407) 881-3308
(CF) (MN) (TF) (ST) (MT) (TR)
(RN) (CD) (CM) (EA) (ED)
(EW) (LL) (OI) (PT)
CIRCLE 868

Pico Electronics
453 N. MacQuisten Pkwy.
Mt. Vernon, NY 10522
(914) 699-5514
(SU)
CIRCLE 869

Piezo Crystal Co.
100 "K" St.
Carlisle, PA 17013
(717) 249-2151
(QC) (CY)
CIRCLE 870

Piezo Technology Inc.
2525 Shader Rd.
Orlando, FL 32804
(407) 298-2000
(QC) (SC) (CL) (CY) (TC)
(VC) (CK) (SO)
CIRCLE 871

Prem Magnetics Inc.
3521 N. Chapel Hill Rd.
McHenry, IL 60050
(815) 385-2700
(AF) (RF) (SU)
CIRCLE 872

Quality Technologies Corp.
Custom/IR Products
2340 Trinity Mills, #330
Carrollton, TX 75006
(214) 418-2946
(IE) (IS) (LI) (OS) (PD) (PR)
CIRCLE 873

Quality Technologies Corp.
610 N. Mary Ave.
Sunnyvale, CA 94086
(408) 720-1440
(IE) (IS) (LL) (LI) (OS) (OI)
(PD) (PR)
CIRCLE 874

RCD Components Inc.
520 E. Industrial Park Dr.
Manchester, NH 03109
(603) 669-0054
(AU) (CF) (CR) (CE) (MN)
(TF) (TH) (GL) (HR) (MO)
(WW) (CH) (RN) (CN) (AF)
(IF) (RF) (SU) (PL)
CIRCLE 875

Raltron Electronics Corp.
2315 N.W. 107th Ave.
Miami, FL 33172
(305) 593-6033

(MC) (QC) (SC) (CL) (CY)
(TC) (VC) (CK) (SO)
CIRCLE 876

Renco Electronics Inc.
60 Jeffry Blvd. East
Deer Park, NY 11729
(516) 586-5566
(AF) (IF) (RF) (SU) (PF)
CIRCLE 877

Robert G. Allen Co. Inc.
7267 Coldwater Canyon
North Hollywood, CA 91605
(818) 765-8300
(CC) (CF) (CR) (CE) (TH)
(MO) (WW) (CH) (RN) (CD)
(CM) (EA) (EW) (FL) (FP)
(FY) (FT) (CP) (CN) (VB) (IE)
(IS) (LL) (LI)
CIRCLE 878

Rohm Corp.
3034 Owen Dr.
Antioch, TN 37103
(615) 641-2020
(CF) (MN) (MO) (CH) (RN)
(CM) (CP) (EM) (IE) (IS) (LL)
(LI) (PR)
CIRCLE 879

SI Tech
P.O. Box 609
Geneva, IL 60134
(708) 232-8640
(FC) (ON) (EM) (OI)
CIRCLE 880

Saronix
151 Laura Lane
Palo Alto, CA 94303
(415) 855-6887
(MC) (QC) (SC) (CL) (CY)
(TC) (VC) (CK) (SO)
CIRCLE 881

Shogyo International Corp.
287 Rt. 25A
Great Neck, NY 11021-4799
(516) 466-0911
(AF) (RF) (LL)
CIRCLE 882

Shokai Far East Ltd.
9 Elena Ct.
Peekskill, NY 10566
(914) 736-3500
(AU) (CF) (CE) (MN) (HR)
(MO) (WW) (CH) (ST) (MT)
(TR) (RN) (CD) (EA) (CP)
(CN) (VB) (AF) (IF) (RF) (SU)
(QC) (SC) (CL) (CY) (CK)
(SO) (IE) (IS) (LL) (LI) (PT)
CIRCLE 883

Siecor Corp.
P.O. Box 489
Hickory, NC 28603-0489
(704) 327-5000
(FC) (ON)
CIRCLE 884

Siemens Components Inc.
Special Products Div.
186 Wood Ave. South
Iselin, NJ 08830
(908) 906-4300
(CM) (EA) (ED) (EW) (FL)
(FP) (FY) (CP) (PF)
CIRCLE 885

Siemens Fiber Optic Components
20 F Commerce Way
Totowa, NJ 07512
(201) 890-1606
(ON) (EM) (OS)
CIRCLE 886

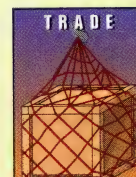
(see p. 114 for key)

(continued on p. 114)

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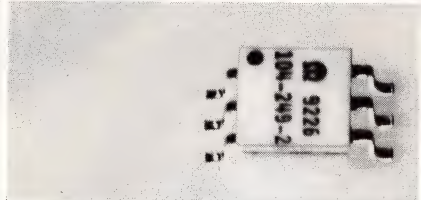
Mailing Address _____

Order by FAX: 216/696-6413 or call 216/696-7000, x 4137

PASSIVE COMPONENTS

▼ RESISTOR NETWORK COMES ON FINE PITCH

A 42-lead, double-upright-style resistor network features 25-mil lead



spacing with up to 40 ultra-stable thin-film resistor elements. Terminations are gold-to-gold with external leads attached directly to gold pads on a ceramic substrate. Resistance range is 50 Ω to 100 k Ω with absolute tolerances from 1% to 0.1%. Ratio tolerances are from 0.5% to 0.1%. Absolute TCR is ± 50 ppm/ $^{\circ}\text{C}$ at ± 25 ppm/ $^{\circ}\text{C}$. Power rating is 50 mW/element typical at 25 $^{\circ}\text{C}$ /0.9 W/package.

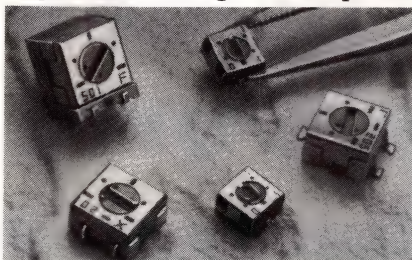
Ohmtek Inc.

2160 Liberty Dr.
Niagara Falls, NY 14304
(716) 283-4025

► CIRCLE 609

▼ MINI TRIMMING POTS KEEP PROFILES LOW

Applications calling for a low profile



and an extended resistance range are suitable for the G3 and G4 Series of micro-miniature trimming potentiometers. Both series are available in top-adjust versions. The G4 Series is also offered in a side-adjust configuration. G3 types are 3.4 by 3.2 mm and stand 2 mm tall. Values range from 100 Ω to 1 M Ω . The G4 types are 5 by 4.5 mm and are 2.8 mm tall. The series ranges from 10 Ω to 2 M Ω . Each series is available with either J-lead or gullwing terminals and operates in a temperature range of -55 to 125 $^{\circ}\text{C}$. Pricing is \$1.55 for the G3 and

\$0.71 for G4 trimmers in lots of 100. Delivery is in six to eight weeks.

Tocos America

1177 E. Tower Rd.
Schaumburg, IL 60173
(708) 884-6664

► CIRCLE 610

▼ TRIMMER CAPS LIFT Q OVER FREQUENCY

A high Q over a broad frequency range, a high operating voltage of 400 V dc, and excellent temperature stability are characteristics of the Cera-Trim II ceramic trimmer capacitor. The units are suitable for a wide range of environmental conditions. The single-turn, surface-mount capacitor comes in a range of values from 0.5 to 2 pF to 5 to 15 pF. Pricing is \$0.85 in lots of 1000. Delivery is from stock to six weeks.

Johanson Mfg. Corp.

Rockaway Valley Rd.
Boonton, NJ 07005
(201) 334-2676

► CIRCLE 611

PASSIVE-COMPONENT MANUFACTURERS

Solitron Devices Inc.
Semiconductor Group
1301 Electronics Way
West Palm Beach, FL 33407
(407) 848-4311
(CR) (MN) (TH) (HR)
(CH) (TR) (RN)
CIRCLE 887

Spectrol Electronics Corp.
4051 Greystone Dr.
Ontario, CA 91761
(909) 923-3313
(ST) (MY) (TR)
CIRCLE 888

Sprague-Goodman Electronics
134 Fulton Ave.
Garden City Park, NY 11040
(516) 746-1385
(AI) (CM) (FL) (FY)
(GC) (MI) (VB) (SU)
CIRCLE 889

Standard Crystal Corp.
9940 E. Baldwin Pl.
El Monte, CA 91731
(818) 443-2121
(MC) (QC) (SC) (CY)
(TC) (VC) (CK) (SO)
CIRCLE 890

State of the Art Inc.
2470 Fox Hill Rd.
State College, PA 16803-1797
(814) 355-8004
(TF) (TH) (HR) (SU)
CIRCLE 891

Tele Quartz Group GmbH
Landstrasse, D-74924
Neckarbischofsheim 2
Germany

(49) 07268/8010
(MC) (QC) (SC) (CL) (CY)
(TC) (VC) (CK) (SO)
CIRCLE 892

Thermometrics Inc.
Bowthorpe
808 U.S. Hwy. 1
Edison, NJ 08817
(908) 287-2870
(MO) (IS)
CIRCLE 893

Toko America Inc.
1250 Feehanville Dr.
Mount Prospect, IL 60056
(708) 297-0070
(AF) (IF) (RF) (SU) (PL) (PF)
CIRCLE 894

Toshiba Marcon Electronics America Corp.
998 Forest Edge Dr.
Vernon Hills, IL 60061
(708) 913-9980
(MO) (CM) (EA) (ED)
(EW) (FP) (FY) (CP)
CIRCLE 895

US Conec Ltd.
P.O. Box 2306
Hickory, NC 28603-2306
(704) 323-8883
(ON)
CIRCLE 896

Valor Electronics Inc.
9715 Business Park Ave.
San Diego, CA 92131
(619) 537-2600
(RF) (SU) (PL) (PF)
CIRCLE 897

Valpey-Fisher Corp.
75 South St.
Hopkinton, MA 01748
(508) 435-6831
(MC) (QC) (SC) (CY)
(TC) (VC) (CK) (SO)
CIRCLE 898

Vectron Laboratories Inc.
166 Glover Ave.
Norwalk, CT 06850
(203) 853-4433
(CY) (TC) (VC) (CK) (SO)
CIRCLE 899

Vishay Electronic Components U.S.
1122 213rd St.
Columbus, NE 68601-3647
(402) 563-6350
(MN) (TF) (TH) (HR) (MO)
(WW) (CH) (ST) (MT) (TR)
(RN) (ED) (EW) (FL) (FP)
(FY) (CP) (AF) (IF) (RF)
(SU) (PF) (CK) (SO)
CIRCLE 900

Vishay Resistors Systems
63 Lincoln Hwy.
Malvern, PA 19355
(215) 251-5267
(AU) (TF) (TH) (GL)
(HR) (CH) (TR) (RN)
CIRCLE 901

(MN) Metal/non-metal film
(TF) Thick film
(TH) Thin film
(GL) Glass
(HR) High resistance
(MO) Metal oxide
(WW) Wire-wound
(CH) Chip
(CO) Conductive plastic
(ST) Single-turn pot
(MT) Multi-turn pot
(TR) Trimmers
(RN) Resistor networks

Capacitors

(AI) Air
(CD) Ceramic/disk
(CM) Ceramic/multilayer
(EA) Electrolytic/aluminum
(ED) Electrolytic/tantalum dry slug
(EW) Electrolytic/tantalum wet
(FL) Film/polycarbonate
(FP) Film/polyester
(FY) Film/polypropylene
(FT) Film/polystyrene
(FF) Film/polysulfone
(CG) Glass
(MI) Mica
(TE) Teflon
(VA) Vacuum
(CP) Chip
(CN) Capacitor networks
(VB) Variable capacitors

(PL) Passive delay lines
(PF) Passive filters

Crystals and Oscillators

(MC) Microprocessor crystals
(QC) Quartz crystals
(SC) Surface-mounted crystals
(CL) Crystal filters
(CY) Crystal oscillators
(TC) Temperature-controlled oscillators
(VC) Voltage-controlled oscillators
(CK) Clock oscillators
(SO) Surface-mounted oscillators

Optoelectronics

(EL) Electroluminescents
(FC) Fiber-optic cables
(ON) Fiber-optic connectors
(EM) Fiber-optic emitters/detectors
(IE) Infrared emitters
(IS) Infrared sensors
(LL) LEDs, light-emitting
(LI) LEDs, IR-emitting
(OS) Optical switches
(OI) Optocouplers/isolators
(PH) Photocells
(PC) Photoconductive cells
(PD) Photodarlingtons
(PT) Photodiodes and arrays
(PR) Phototransistors
(UV) UV sensors

KEY

Resistors

(AU) Audio
(CC) Carbon composition
(CF) Carbon film
(CR) Ceramic
(CE) Cermet

Inductors, Coils, and Chokes

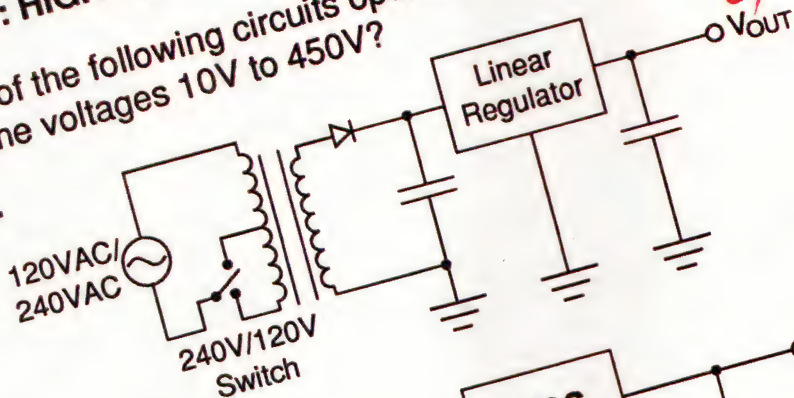
(AF) Audio frequency
(IF) Intermediate frequency
(RF) Radio frequency
(SU) Surface-mounted

CIRCUIT DESIGN FINAL EXAM

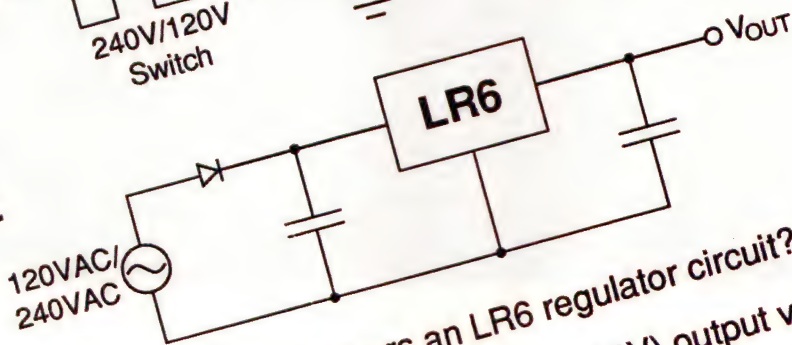
Section IV: HIGH VOLTAGE POWER SUPPLIES

1. Which of the following circuits operates automatically from line voltages 10V to 450V?

☐ a.



☒ b.



2. Which of the following favors an LR6 regulator circuit?

- ☐ a. Fixed (10V) or adjustable (5V to 12V) output voltage
- ☐ b. Significant savings in cost and board space (TO-92)
- ☐ c. Surface Mountable (SOT-89 and SO-8)
- ☒ d. All of the above

3. What is the maximum voltage you can apply to the input of the LR6?

- ☐ a. 12V
- ☐ b. 36V
- ☐ c. 44V
- ☒ d. 450V

A+
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Supertex LR6 is the answer!

Call for a designer's package containing samples, data sheets, application notes, and information.

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1-800-222-9883 in California



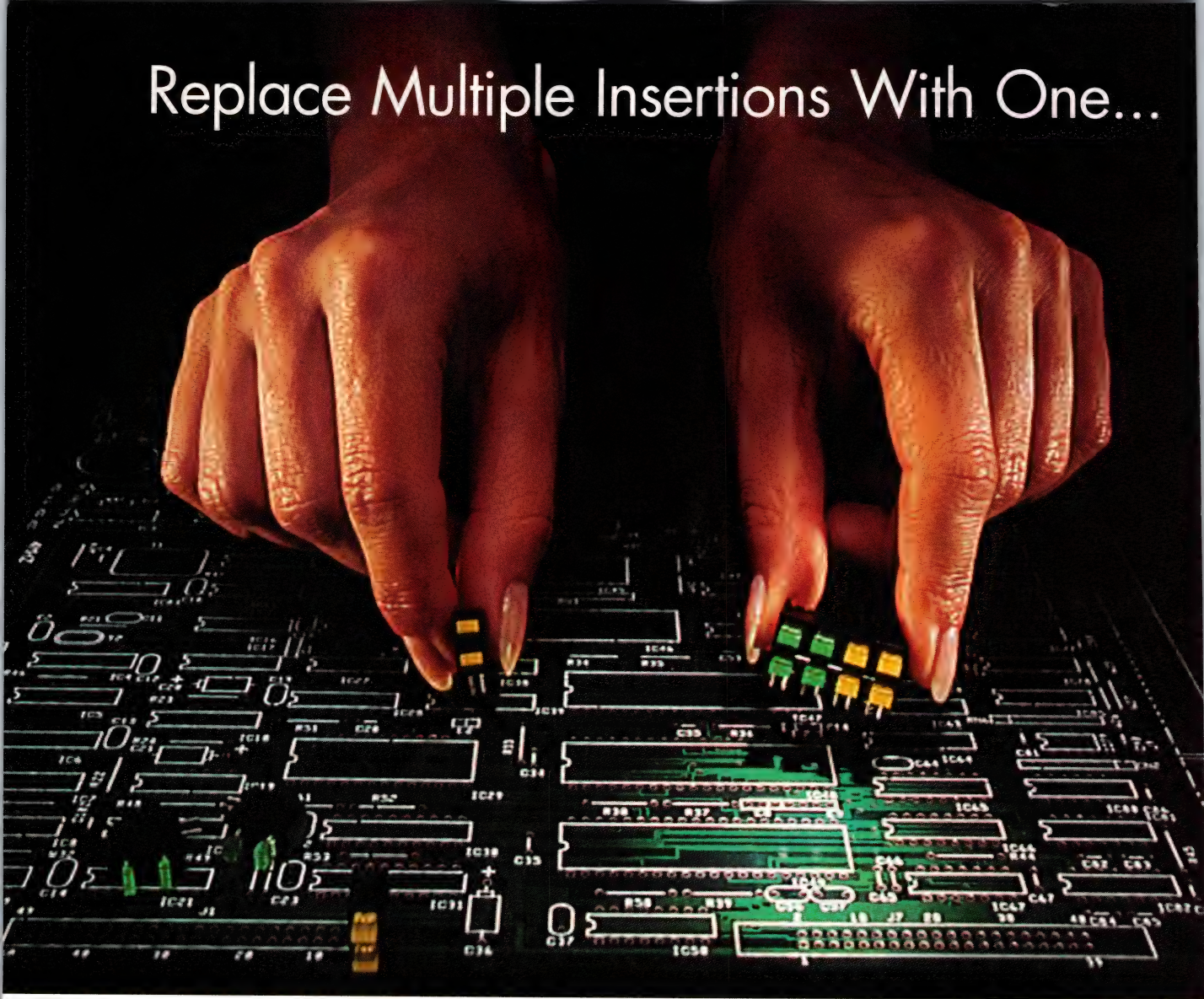
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Replace Multiple Insertions With One...



And Lower Your Production Costs.

Dialight LED arrays reduce the number of insertions for significant savings in production costs.

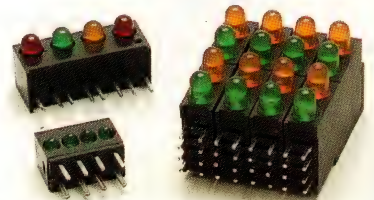
It's that simple. We can supply you with the widest variety of arrays available anywhere — from 2 to 12 wide... up to 4 high... in any color combination... in back-light or thru-panel... up, down, sideways or rectangular. What's more, if you require a custom configuration, Dialight can provide that too.

And consider this: Dialight's "block" housing delivers precise lead and LED alignment every time. The array package is designed with ease of insertion in mind — as a single piece — and does not use the cumbersome inter-lock approach you may have seen elsewhere.

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Contact: Dialight Corp., Dept. CAD994, 1913 Atlantic Ave., Manasquan, NJ 08736.



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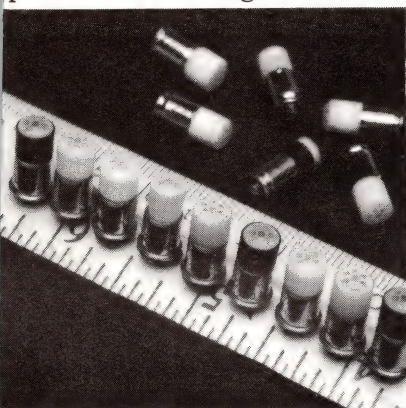
JAPAN
Tel: 403-3348-0611
Fax: 403-3348-0623

SINGAPORE
Tel: 65-4473735
Fax: 65-4472482

UK/IRELAND
Tel: 444 0638.665161
Fax: 444 0638.660718

▼ MIDGET-BASE LEDs REPLACE INCANDESCENTS

A family of midget flange- and groove-based, multi-chip LED lamps are direct plug-compatible replacements for midget incandescent or neon lamps. Applications are in miniature switches, indicators, annunciators, and more. LED lamps operate up to ten times as long as the incan-



descents they replace and are resistant to vibration and shock. Lamps can be supplied for all common indicator-supply voltages from 5 to 120 V dc or ac (50 to 400 Hz). The products feature built-in current-limiting resistors and polarity-protection diodes. Call for pricing and delivery.

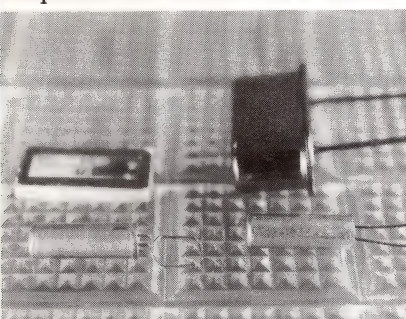
Ledtronics Inc.

4009 Pacific Coast Hwy.
Torrance, CA 90505
(310) 534-1505

► CIRCLE 612

▼ CRYSTAL RESONATOR MEETS WIRELESS NEEDS

Claimed as the first SMD and through-hole AT-strip resonator available in a 2-by-6-mm metal can, the MXAT resonator is offered in frequencies from 14 to 25 MHz. Pre-



viously, such devices were available only in ceramic packages and larger metal cans. The MXAT was the solution for the crystal requirement of the Rockwell RC224ATF integrated V.22 bis data/fax modem with AT

and Class 1 commands in a wireless application. The product required a crystal with a frequency of 16.00312 MHz ± 20 ppm. Pricing for that device is \$1.77 in lots of 100,000 with delivery in six to eight weeks.

Micro Crystal

A Division of SMH
702 W. Algonquin Rd.
Arlington Heights, IL 60005
(708) 806-1485

► CIRCLE 613

▼ SHIELDED INDUCTOR MINIMIZES COUPLING

Minimal magnetic coupling to other components in RF circuitry is achieved by using the model ISC-1210 shielded surface-mount inductor. Engineered for high-speed SMT applications, the device is supplied in EIA-481 tape-and-reel packaging. It fits the standard 1210 footprint. In-



ductance values range from 0.01 μ H to 100 μ H. Standard tolerances are $\pm 20\%$ and $\pm 10\%$ depending on value. Other tolerances are available on request. A 1- μ H inductor with $\pm 10\%$ tolerance goes for \$0.214 in lots of 4000. Delivery is in six weeks.

Dale Electronics Inc.

East Hwy. 50
P.O. Box 180
Yankton, SD 57078-0180
(605) 665-9301

► CIRCLE 614

▼ PANEL-MOUNT POT OFFERS WIDE RANGE

Designed for panel control or pc-board applications, the model 248/249 is a 1/2-in.², single-turn potentiometer. The device is qualified for a rotational life of 50,000 cycles (the model 248) and 25,000 cycles (model

249). Using conductive plastic and cermet elements, respectively, the devices offer resistance ranges from 100 Ω to 500 k Ω (model 248) or to 1 M Ω (model 249). Power rating is 0.5 W and 1 W, respectively. Two shaft diameters enhance the range of control-knob options. Call for pricing.

Spectrol Electronics Corp.

4051 Greystone Dr.
Ontario, CA 91761
(909) 923-3313

► CIRCLE 615

▼ SMT CERAMIC CAPS BOOST VALUE RANGE

Additional capacitances are now available for the MCS Series of ceramic chip capacitors. Values from 10,000 pF to 6.8 million pF are offered in these larger versions of the MCS line. The large capacitors feature the terminations made with a dry-film process that overcome several problems associated with conventional plated devices. The capacitors need not be immersed in plating solutions that can deposit conductive ions on the ceramic, causing insulation-resistance failures. Pricing ranges from \$0.018 to \$0.67 in lots of 10,000. Delivery is from stock to 10 weeks.

ROHM Corp.

3034 Owen Dr.
Antioch, TN 37013
(615) 641-2020, ext. 117

► CIRCLE 616

▼ ELECTROLYTIC CAPS START AC MOTORS

Specially designed to provide the torque necessary to start ac motors and other intermittent ac applications, the MSC Series of ac electrolytic capacitors features two 0.25-in. quick-connect terminals and a round moisture- and oil-resistant plastic case. The device operates from 110 to 330 V ac and has a capacitance range of 21 to 1200 mF (110/125 V), 21 to 324 mF (221/250 V), and 21 to 259 mF (330 V). They operate from -40 to 65°C and have an operating frequency of 47 to 60 Hz and power factor of 10% maximum (12% at less than 30 mF). Call for pricing.

NTE Electronics Inc.

44 Farrand St.
Bloomfield, NJ 07003
(800) 683-6837

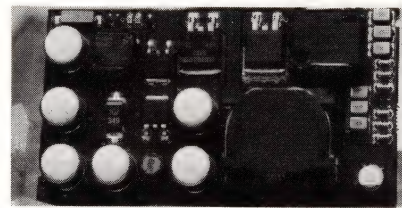
► CIRCLE 617

POWER SOURCES

▼ CONVERTER MODULES POWER DISK DRIVES

A series of power-converter modules is specifically designed as a distributed power supply for disk drives and other mass-storage devices. The DiskPower converter modules operate from an input range of 18 to 36 V dc (models TC050AB and TC070AB) or 36 to 72 V dc (models TW050AB

and TW070AB). They offer separately regulated outputs of +5 and +12 V dc. Overvoltage and overcurrent protection is provided in all modules. The 12-V output supports peak spin-up surges of 3.5 A (50-Series) and 5 A (70-Series). The modules feature extremely low noise levels of 60 mV p-p on +12 V. Samples are available now. Production quantities start at \$35 for



the TC050AB.

AT&T Microelectronics
Room 21Q-133BA
555 Union Blvd.
Allentown, PA 18103
(800) 372-2447, Dept. P30
► CIRCLE 618

SIEMENS

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READER SERVICE 108

▼ LOW-PROFILE SWITCHER PUMPS OUT 600 W

A series of low-profile switching power supplies provides 600 W of output with a power density of 3.5 W/in.³. The 126-Series supplies offers any number of configurations depending on customer needs. Ac-input range is from 90 to 132 V ac and 180 to 264 V ac, single-phase (user selectable). Operating at a fixed 70 kHz, the model 126-01 offers +5 V dc at up to 100 A, +12 V dc at up to 20 A, -12 V dc at up to 10 A, and +12 V dc at up to 10 A. Pricing is from \$435 in lots of 1000. Delivery is in six to eight weeks.

Conversion Equipment Corp.
330 W. Taft Ave.
Orange, CA 92665
(714) 637-2970
► CIRCLE 619

▼ RF POWER TRANSISTORS DELIVER 2 TO 36 W

A line of six Class-A, RF npn power transistors provides power in the range of 2 to 36 W, depending on the device. The units, which are designed for operation in the 800-to-960-MHz range, are for 24-V UHF large-signal, common-emitter, linear-amplifier applications. The MRF857 is in a stud package, while the MRF857S is in a studless pill package and the MRF858 is in an SOE flange package. The MRF860, 861, and 862 transistors come in push-pull flange packages. Pricing starts at \$14.64 for the MRF857, a 2.1-W device. Samples and small quantities are from stock.

Motorola Inc.
5005 E. McDowell Rd.
Phoenix, AZ 85008
(602) 244-6108
► CIRCLE 620

What a can of worms: impossible electronic and mechanical requirements, multiple vendors, looming deadlines. Make it easy. Throw the whole mess at us. We define quality as total customer satisfaction and maintain carefully controlled manufacturing systems to reduce lead times and costs on complete interconnect systems engineered for smaller and more precise electronic equipment. We're using conductors as small as 44 AWG. High-speed coaxes with up to 93% velocity of propagation. Terminations to standard industry connectors or to specially designed custom connectors, including one that allows conductors to be terminated at a density of over 500 contacts per square inch. And terminations on flex circuits with center line spacing smaller than 0.025". That's today. Tomorrow? Just tell us what you're fishing for.



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— an AMP company

Precision Interconnect, 16640 S.W. 72nd Avenue, Portland, OR 97224 (503) 620-9400 Fax (503) 620-7131. Sales offices in U.S., Europe and Japan.

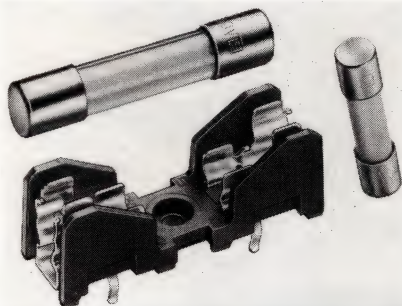
SOLUTIONS FOR YOUR MESSIEST PROBLEMS.



INTERCONNECTIONS

▼ FUSE BLOCK TAKES BOTH AMERICAN, METRIC TYPES

A dual-fuse clip enables the OGD fuse block to accept either 1/4-by-1-1/4-in. fuses in its upper portion or 5-by-20-mm fuses in its lower portion. Built in accordance with IEC 65, subclause 14.5.2/VDE 0860, the block makes it impossible to install both



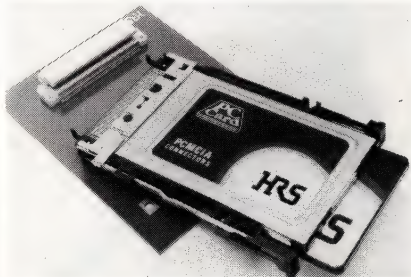
types at the same time. The block eliminates the need for soldering or desoldering leaded fuses. It's UL- and CSA-approved for 16 A/250 V and VDE-, SEMKO-, and SEV-approved for 10 A/250 V. Pricing is \$0.38 in lots of 1000. Delivery is from stock.

Schurter Inc.
1016 Clegg Ct.
Petaluma, CA 94954
(707) 778-6311

► CIRCLE 621

▼ DUAL-SLOT CONNECTOR HOUSES PCMCIA CARDS

Two-piece construction provides full access for visual inspection of solder terminations in the IC8, a dual-slot SMT-to-board pc-card connector.



Two cards per device is key for mobile-computer designers who need to meet PCMCIA 2.0 and JEIDA Version 4.1 requirements for type I, II, and III cards. The connector comes in either standard or reverse configuration and accepts all three card types for insertion in either slot. Ejectors are provided for each slot, and standoffs are available so that components can be placed underneath the ejector portion. Pricing is

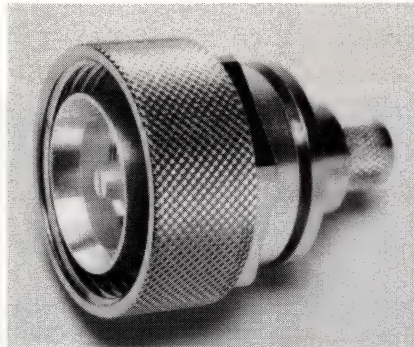
\$11 in OEM lots. Small quantities are delivered from stock.

Hirose Electric (U.S.A.) Inc.
2688 Westhills Ct.
Simi Valley, CA 93065-6235
(805) 522-7958

► CIRCLE 622

▼ 7/16 COAX CONNECTORS MEET DIN STANDARDS

The 7/16 series of coaxial connectors conforms to DIN 47223 and other applicable IEC, VG, and CECC standards. The 50-Ω connectors have an M 29 x 1.5 mating thread and combine durability, high power-handling



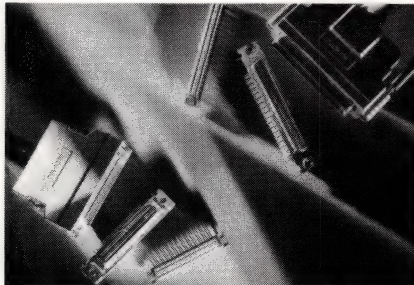
capability, and a VSWR as low as 1.07:1 at 2 GHz, depending on the cable used. They're constructed of nickel-plated brass with Teflon insulators. The line includes a variety of plugs and receptacles, with custom configurations also available. Call for pricing and delivery.

Delta Electronics Mfg. Corp.
P.O. Box 53
Beverly, MA 01915
(508) 927-1060

► CIRCLE 623

▼ SHIELDED-I/O LINE MEETS SCSI SPECS

A high-density, shielded-I/O line provides a reliable, cost-effective mechanical interface in full conformance with the requirements of



ANSI X3T10 group's SCSI-2 and SCSI-3 (SPI) standards. Applications for the SCSI+ line include mainframes, file servers, workstations,

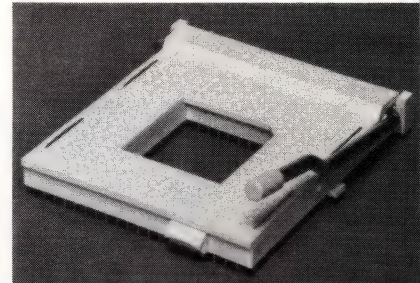
disk and tape drives, RAID, CD ROMs, and PCs. As a pricing example, in quantities of 1000, a 50-circuit shielded plug goes for \$4.43. Call for delivery information.

Molex Inc.
2222 Wellington Ct.
Lisle, IL 60532
(800) 78-MOLEX

► CIRCLE 624

▼ PGA ZIF SOCKETS TAKE 238-PIN PENTIUMS

The 675 Series zero-insertion-force sockets are designed to accept 237-pin (socket no. 3) and 238-pin (socket



no. 2) Intel Pentium Overdrive Ready devices. The sockets feature an easy-to-use single-level actuation handle to facilitate PGA-device insertion and withdrawal without special tools. Typical unit price in small quantities is \$5. Delivery is from stock to three weeks.

Andon Electronics Corp.
4 Court Dr.
Lincoln, RI 02865
(401) 333-0388

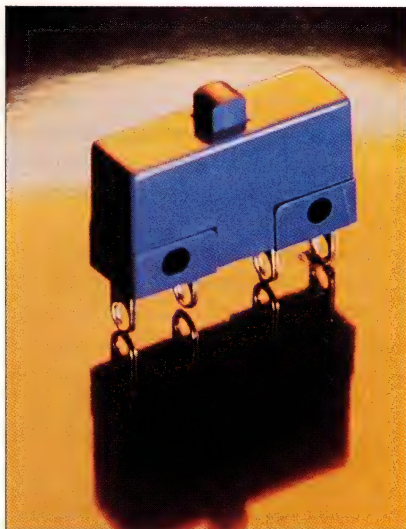
► CIRCLE 625

▼ TWO-TIER TERMINAL DOUBLES PCB SPACE

The RIACON two-tier pc-board terminal strips double the available termination space on boards. The Type 96 and 97 Series modular devices are offered in two and three positions and are rated at 300 V at 20 A. Their connecting system securely clamps single or multiple connectors in a wire range of 12 to 26 AWG. In addition, the termination system eases mechanical stress on solder joints. Center-to-center spacing is 5 mm for Type 96 and 5.08 mm for Type 97. Call for pricing and delivery.

RIA electronic Inc.
15 Meridian Rd.
P.O. Box 447
Eatontown, NJ 07724
(908) 389-1300

► CIRCLE 626



DOUBLE-BREAK SUBMINIATURE BASICS

May be subminiature in size but these basics switch up to 10 amperes with 100,000 minimum cycle life; over 1 million cycle mechanical life! Constructed in accordance with MIL-S-8805/7. UL recognized. Precision operating points.

Replaces ITW Switches Type 16.
Ask for B5 series.

READER SERVICE 133



ENVIRONMENT-FREE SEALED SWITCHES

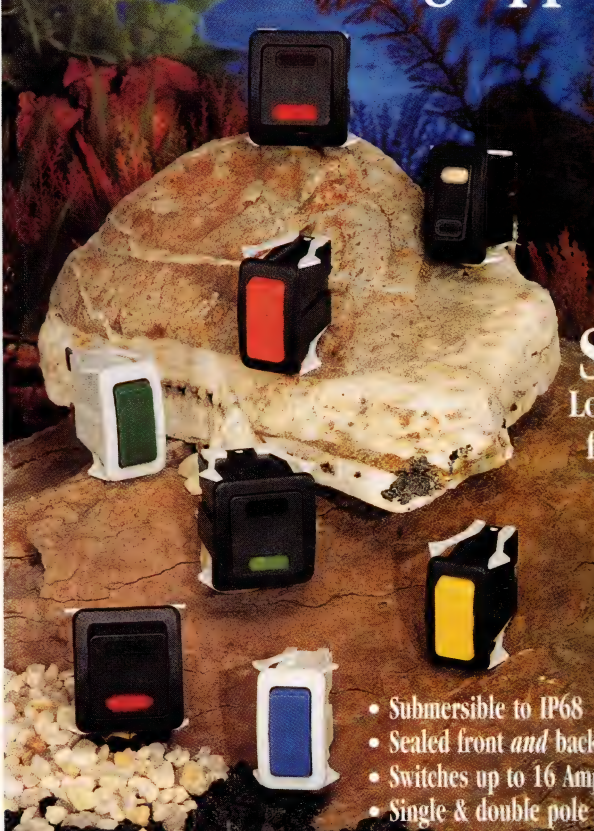
Withstands immersion and corrosive atmospheres. Designed for rugged duty both mechanically and electrically. One-piece stainless steel housings sealed at the plunger with ring seals and at the base with glass-to-metal header. **Replaces C-H/Eaton H11, Microswitch EN and ITW Type 63.** Ask for P6 series.

READER SERVICE 134

OTTO

CONTROLS

For Demanding Applications



Sealed Rocker Switches

Low cost, Snap-in,
for Wet & Dusty
Environments

- Submersible to IP68
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CONTROLS

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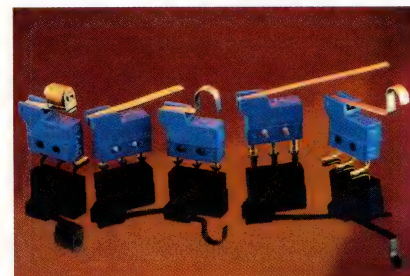


SEALED MINI TOGGLES

Rugged and highly reliable, these toggles weigh 25% less than others. Positive detent. Non-teasible contact transfer. One or two poles, momentary, maintained and lever-lock-out operation. Rated 5 A. Qualified to MIL-S-83731.

Replaces C-H/Eaton 88, Microswitch TW. Ask for T3 series.

READER SERVICE 135



SINGLE-BREAK BASICS

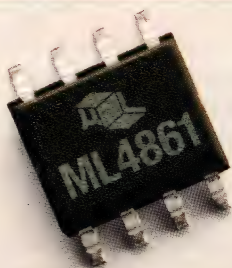
Commercial and Military grades, available in two widths. Switch up to 7 amperes. Available with integral levers as B2-5 series. UL recognized and CSA certified. **Replaces C-H/Eaton SS10 & SS30, Microswitch SX, Unimax MM5 & MM6.** Ask for B2 series.

READER SERVICE 136

READER SERVICE 102

See us at Wescon booth 2056

More power to you.



The ML4861 is the industry's **smallest, simplest, most efficient** power converter for 1 to 3 cell battery-powered systems. Available in 6V, 5V, 3.3V and adjustable output versions, the ML4861 makes it easier to bring your next hand-held product to market.

- Simple, minimal component boost switcher requires only one inductor and one capacitor.
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- Highest conversion efficiency – >90% over two decades of output current.
- <50µA of quiescent current.
- Built-in undervoltage flag at 900mV (standard alkaline, NiCd & NiMH end-of-life).

For more information contact your Micro Linear distributor: Insight Electronics, Inc., San Diego, CA 1-800-677-6011; Pioneer Technology, Gaithersburg, MD 1-800-227-1693; Interface Electronics Corp., Hopkinton, MA 1-800-632-7792.

 **Micro Linear**

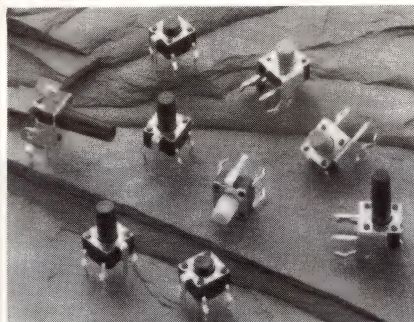
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READER SERVICE 157

SWITCHES & RELAYS

▼ TACTILE SWITCHES HAVE SHORT TRAVEL

The microminiature FSM J Series of pushbutton switches is traditionally used in conjunction with keycaps or in keyboard applications, but is increasingly finding its way into new industrial and consumer product applications. Such applications require reliable, high-cycling pushbutton switches as well. The FSM J Series

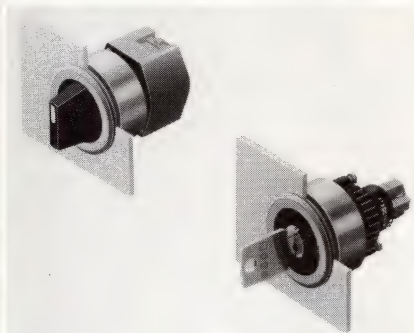


units provide positive tactile feel in a pushbutton switch with less than 0.02-in. actuation travel. They're offered in vertical and right-angle configurations, with or without a ground terminal, and in a variety of actuator lengths. A silver-plated dome spring contact provides a minimum of 100,000 cycles. Contact leads are insert-molded to help prevent solder and flux contamination during printed-circuit-board processing. Suggested resale pricing is \$0.235 in lots of 5000. Samples and data sheets are available.

Augat Inc.
452 John Dietsch Blvd.
P.O. Box 2510
Attleboro Falls, MA 02763
(508) 699-7646

► CIRCLE 627

▼ FLUSH-MOUNT ADAPTER MAINTAINS SWITCH SEALS



A flush-mount adapter maintains the integrity of the sealing capability of EAO's Series 04 and 14 switching systems, which are sealed to IP 65

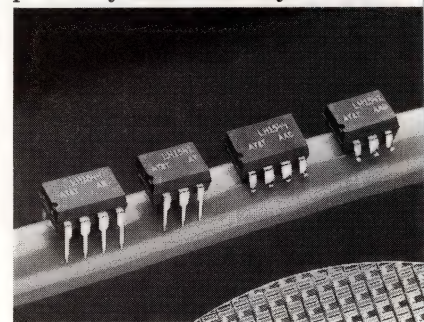
and NEMA 4 and 13 specifications. The adapter is well suited for using those switches in oil- and water-tight applications where the aesthetics of a clean panel look is required. The miniature, heavy-duty Series 04 and the rugged Series 14 switches mount into a standard 30.5-mm round panel hole when the adapter is used. Pricing for the Series 04/14 flush-mount adapter is \$8.62. Delivery is from stock to four weeks after receipt of order.

EAO Switch Corp.
198 Pepe's Farm Rd.
Milford, CT 06460
(203) 877-4577

► CIRCLE 628

▼ SOLID-STATE RELAYS OFFER LOW CAPACITANCE

For small-signal analog switching and high-speed dc instrumentation applications, the LH1541 1 Form A and LH1544 dual 1 Form A solid state relays offer a reliable alternative to electromechanical and reed relays. Both are miniature, optically coupled devices that provide a linear high-voltage MOSFET switch output. They feature a very low contact



capacitance of 5 pF, allowing the relays to switch at much higher frequencies than standard solid-state relays. The fast actuator speeds enable data to be sampled in multiplexer applications at typical rates of under 250 µs. Packaging is in 6-pin, plastic DIP, or SMT gull-wing for the LH1541. The LH1544's plastic DIP has eight leads and also comes in an SMT gull-wing package. Pricing in OEM volumes is \$1.66 for the LH1541 and \$3.16 for the LH1544. Delivery is from stock.

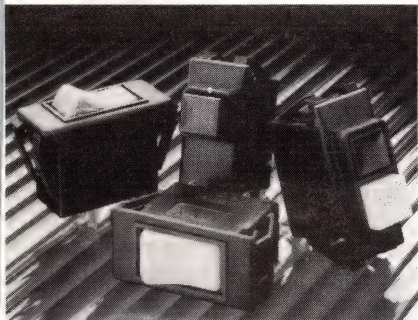
AT&T Microelectronics
Dept. AL-500404200
555 Union Blvd.
Allentown, PA 18103
(800) 372-2447, Dept. P27

► CIRCLE 629

SWITCHES & RELAYS

▼ SWITCHED BREAKER HAS ONE OR TWO POLES

A line of commercial rocker-switch circuit breakers has added two-but-



ton push-ON/push-OFF control and press-to-reset-only options. Often used on industrial equipment, the two-pushbutton Series 3120 breaker fits the same panel cutout as the rocker switch and is available in red and green, black and white, or any combination of those colors. Also offered is the press-to-reset-only option in a two-pole configuration, which eliminates the possibility of accidental shutdown of equipment. The Series 3120 features overload protection on one or both poles and current ratings from 0.1 to 20 A. Call for pricing and delivery.

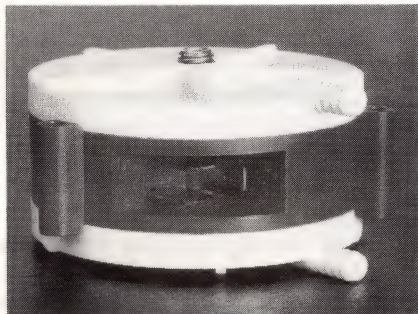
E-T-A Circuit Breakers

7400 N. Croname Rd.
Niles, IL 60714-3982
(708) 647-8303

► CIRCLE 630

▼ TINY PRESSURE SWITCH SENSES LOW LEVELS

A small, extremely sensitive pressure switch is able to sense very low pressure, vacuum, or differential



levels. The model MPL-9300 pressure switch is a single-pole, double-throw unit that ensures a positive make and eliminates any contact bounce. Current-carrying capacity is up to 5 A resistive and 2.5 A inductive loads. Operating pressure is from 0.25 to 34 in. of water (0.0095 to 1.22 psig). Life span is rated for over

200,000 cycles. Call for pricing and delivery.

Micro Pneumatic Logic Inc.

2890 N.W. 62nd St.
Ft. Lauderdale, FL 33309
(305) 973-6166

► CIRCLE 631

▼ FOUR-POLE POWER RELAY STOPS CONTACT CHATTER

A four-pole power relay is available in a variety of contact arrangements for three-phase motor-control applications and resistive and inductive loads. The G7J relay withstands voltage drops of up to 50% of the rated coil voltage for 1 s maximum with no contact chatter to drop out. It provides resistive-load ratings of 25 A (normally open) and 8 A (normally closed) and withstands more than 4 kV between contacts that are of different polarity and between the coil and contacts. Pricing is \$16.25 in lots of 1000. Delivery is from stock to 12 weeks.

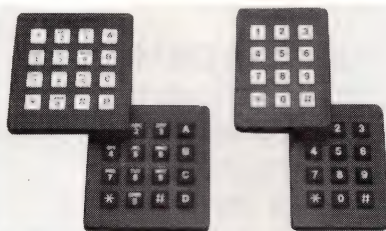
Omron Electronics Inc.

One E. Commerce Dr.
Schaumburg, IL 60173
(800) 55-OMRON

► CIRCLE 632

▼ CONDUCTIVE KEYPADS ENSURE TACTILE FEEL

The Series 96 conductive rubber keypads are constructed in such a way that tactile operator feedback is ensured for the life of the switches, which is rated at 3 million operations.



The keypads are offered in 3-by-4 and 4-by-4 configurations. The housing that captures the rubber keypad and pc board is available in industry-standard top-panel or sub-panel mounting styles. A 3-by-4 keypad with matrix-code output goes for \$11 in single quantities and \$5.94 in lots of 1000. Small quantities are delivered in one to two weeks.

Grayhill Inc.

561 Hillgrove Ave.
LaGrange, IL 60525
(708) 482-2132

► CIRCLE 633

The faster, the better.



Our new ML6580 octal buffer/transceiver is the industry's fastest. Offering you propagation delay of 1.5ns – twice as fast as 3.2ns digital CMOS counterparts. Without a significant increase in power dissipation. Making it a better solution for high-performance computer systems. Our analog approach results in:

- Low ground bounce, typically <400mV.
- Faster settling with minimum output skew.
- Eliminates external termination resistors.
- Schottky clamps to handle undershoot and overshoot.
- Industry-standard pin-out; available in 20-pin SOIC and QSOP packages.

For more information contact your Micro Linear distributor: Insight Electronics, Inc., San Diego, CA (619) 587-1100; Pioneer Technology, Gaithersburg, MD (301) 921-0660; Interface Electronics Corp., Hopkinton, MA (508) 435-0100.

 **Micro Linear**

PACKAGING & MATERIALS

▼ STOCK ENCLOSURES BOAST 12 NEW COLORS

Twelve new color choices are now available in EMCOR's ship-from-stock enclosure program. The options are offered for frames, desks, and accessories, all of which are provided in either smooth or textured finishes. The instant-enclosure program, which ships products within

five days of order, spans electronic cabinetry, computer-support furniture, cooling devices, and a large assortment of accessories. Vertical, slope-front, low-silhouette, and turret-style frames are offered. Call for pricing and delivery.

EMCOR Products
1600 4th Ave. N.W.
Rochester, MN 55901

(507) 289-3371
► **CIRCLE 634**

▼ DC ROTARY FANS COOL CPUs AND MORE

A line of small and miniature dc-voltage rotary fans is designed to cool computers, communication equipment, instrumentation, and more. The JF Series fans are available in 40-, 60-, 80-, and 90-mm sizes. The 40 mm fan provides an airflow of 0.14 cfm. A CPU-cooling module is of



fered in which a fan is fastened on top of a heat sink that's mounted over the CPU. Snap-in design makes for quick, easy installation. Operating voltage is 12 V dc. Call for pricing and delivery.

North American Capacitor Co.
7545 Rockville Rd.
Indianapolis, IN 46214
(317) 273-0090
► **CIRCLE 635**

▼ SHIELDING GASKETS HOLD DOWN CORROSION

Two low-corrosion, aluminum-compatible elastomer compounds are available for shielding-gasket applications. Consil-X is a conductive silicone elastomer that's filled with inert-coated aluminum core particles. CON-EPDM-X is an inert-coated, aluminum-filled compound designed to satisfy nuclear, biological, and chemical requirements. Both compounds suit applications which preclude the presence of silver, but which require high shielding effectiveness. The material comes in sheets, continuously extruded strips, and die-cut or molded gaskets. Call for pricing and delivery.

Technit
129 Dermody St.
Cranford, NJ 07016
(908) 272-5500
► **CIRCLE 636**

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Department LL
Pueblo, Colorado 81009**

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UL-APPROVED RACKS COME IN WIDE VARIETY

All requirements of UL 1244, the standard for electrical and electronic measuring and testing equipment, have been met by the Miracel Series of racks. The rack is designed for a wide range of applications and is offered in a number of configurations. Options include mounting heights from 23U (40.25 in.) through 46U (80.5 in.), adjustable mounting widths from 19 in. through 24 in., metric 18 and 20 modules, NEMA 12 versions, LAN versions, and more. Call for pricing and delivery.

Knurr USA Inc.

1890 N. Voyager Ave.
Simi Valley, CA 93063
(805) 526-7733

► CIRCLE 637

STANDARD MCM PACKAGES HAVE 368 LEADS

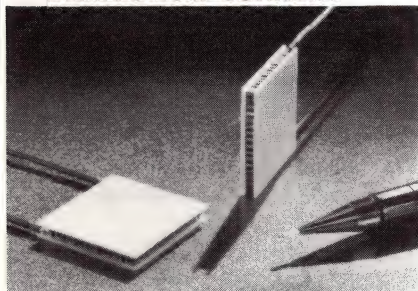
A standard ceramic multichip-module (MCM) package with 368 leads on a 0.65-mm pitch is available. The package meets the JEDEC MO-148 outline requirements. Its body size is 64 mm² and its cavity size is 53 mm² for a ceramic or silicon substrate. A Kovar seal ring is offered for seam sealing, and standard internal power and ground planes are included. The signal-trace impedance is 50 Ω . This package, as well as a 308-lead version, is offered with open tooling and quick-turn delivery. They're both customizable to meet specific needs, including low-cost single-layer versions. Call for pricing and delivery information.

Coors Electronic Package Co.

511 Manufacturers Rd.
Chattanooga, TN 37405
(615) 755-5408

► CIRCLE 638

THERMOELECTRIC COOLER DRAWS LOW CURRENT



A line of thermoelectric coolers (TECs) includes a model claimed as

the smallest and lowest-current 12-V TEC available. The CP0.8-127-05L and -06L TECs have a footprint of just 25 mm by 25 mm and heights of 3.1 mm and 3.4 mm, respectively. They are rated at 2.6 and 2.1 A, respectively, and 15.4 V maximum for achieving temperature differentials up to 67°C in localized cooling applications. These 127-couple TECs are

two of nine in a family that ranges from seven to 254 couples. Typical pricing for the -05L TEC is \$12.35 in quantities of 100. Delivery is in four weeks.

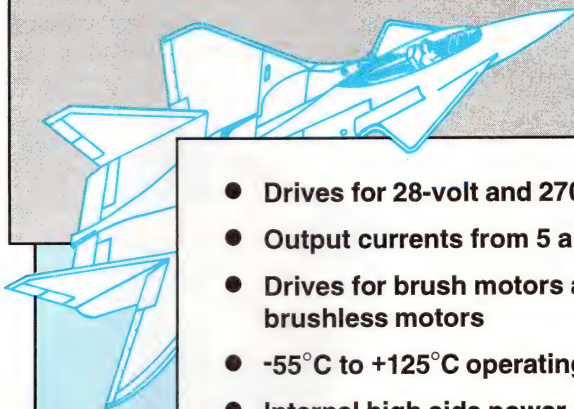
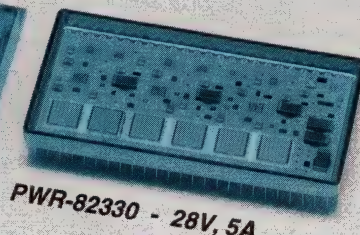
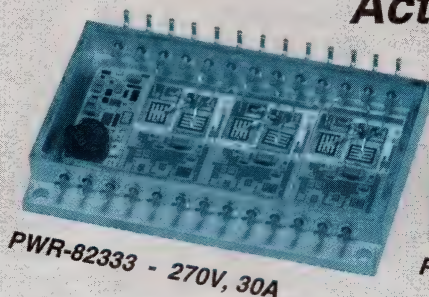
MELCOR

1040 Spruce St.
Trenton, NJ 08648
(609) 393-4178

► CIRCLE 639

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CORPORATION®

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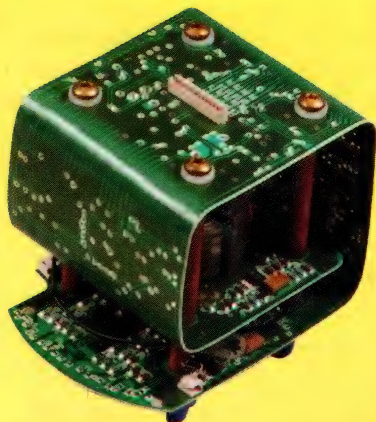


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- 883B processing available

For more information call Power Applications at (516) 567-5600 ext. 7234.

HEADQUARTERS AND MAIN PLANT: ILC Data Device Corporation
105 Wilbur Place, Bohemia, NY 11716-2482, (516) 567-5600, FAX: (516) 567-7358, (516) 563-4331
Toll Free Outside NY 1-800-DDC-1772, Canada 1-800-245-3413
WEST COAST (CA): GARDEN GROVE, (714) 895-9777, FAX: (714) 895-4988
WASHINGTON, D.C. AREA: STERLING, VA, (703) 450-7900, FAX: (703) 450-6610
NORTHERN NEW JERSEY: TOTOWA, (201) 785-1734, FAX: (201) 785-4132
U. K.: 44 (635) 40158, FAX: 44 (635) 32264; **IRELAND:** 353 (21) 341065, FAX: 353 (21) 341568
FRANCE: 33 (1) 4333-5888, FAX: 33 (1) 4334-9762; **GERMANY:** 49 (8191) 3105, FAX: 49 (8191) 47433
SWEDEN: 46 (8) 920635, FAX: 46 (8) 353181; **JAPAN:** (33) 814-7688, FAX: (33) 814-7689

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NEW LITERATURE

▼ CRYSTAL OSCILLATORS STAR IN BROCHURE

A 32-page catalog details a broad range of crystal clock oscillators. Separate sections on various oscillator families illustrate a wide application flexibility. For example, the ultra-miniature, surface-mounted Tiny T line measures just 5 by 7 by 2.3 mm and is available in 3.3- and 5-V versions. The catalog contains complete performance data, listings of special features, package schematics, environmental data, and more. An easy-to-read index listing all models by various parameters facilitates ordering.

MF Electronics Corp.

10 Commerce Dr.

New Rochelle, NY 10801

(914) 576-6570

► CIRCLE 640

▼ MATERIALS CATALOG SPANS BROAD RANGE

A 212-page catalog titled "The World of Electronic Materials" features products for electronic manufacturing and repair and offers problem solvers for diverse areas such as static control, soldering, pc-board materials, EMI/RFI shielding, and



thermal management. Other areas covered include adhesives and coatings, wire harnesses, tubing, sleeving, insulating materials, and pressure-sensitive tape. Information is also included on the company's value-added services.

**Electrical Insulation Suppliers
Inc.**

300 N. Mannheim Rd.

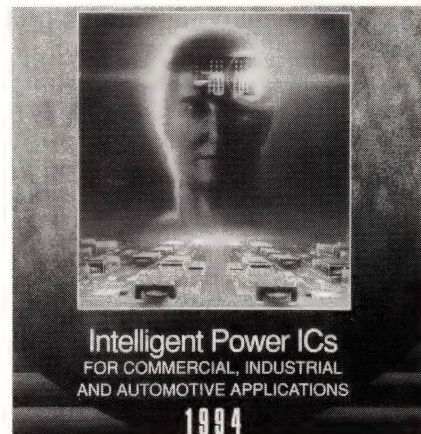
Hillside, IL 60162

(708) 547-5400

► CIRCLE 641

▼ POWER-IC DATA BOOK DESCRIBES 76 PRODUCTS

Seventy-six products, 22 of them new, are described in a 944-page intelligent power-IC data book from Harris. The volume contains 286 pages of application notes, which is up from 152 pages in the 1993 edition. Harris applies the term "intelligent power" to high- and low-side switches and drivers, half- and full-bridge



drivers, ac-dc and dc-dc converters, voltage regulators, pulse-width modulators, and voltage monitors. The book also includes specific automotive products including interface and protocol-handling chips for the SAE's J1850 serial data-bus standard. Long-form data sheets and application notes are included.

Harris Semiconductor

P.O. Box 883

Melbourne, FL 32901

(800) 442-7747, ext. 7265

► CIRCLE 642

▼ COILS AND CHOKES COVERED IN DETAIL

Coils, chokes, and inductors for RF applications are the subject of a large illustrated catalog from Stander. The book covers over 5000 standard values of fixed, variable, SMT, and through-hole RF coils. Information on toroidal inductors and common-mode chokes is also included for their specification into switching power supplies, EMI/RFI filter assemblies, and many other applications. The catalog contains dimensional drawings and many tables of specifications on all products.

Stander Electronics

4538 Camberwell Rd.

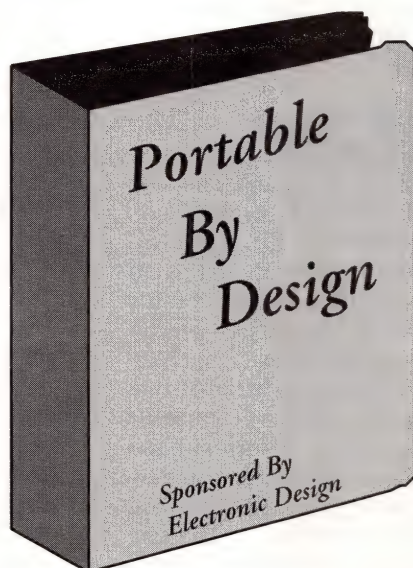
Cincinnati, OH 45219

(513) 871-3777

► CIRCLE 643

Proceedings of Portable By Design

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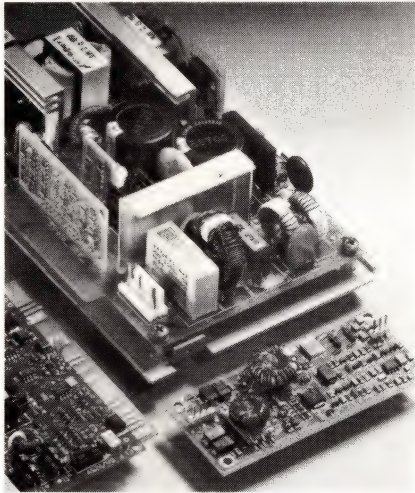
- * Power Circuits
- * Connectivity
- * Input Devices
- * Managing Mechanical/Electrical Design Teams
- * Expandability/Configurability
- * Engineering The Whole System
- * High End Microprocessors
- * Low-Power Microcontrollers
- * Power Management
- * Application Development & Operating Systems
- * Batteries
- * Displays

For additional or ordering information, please call (201) 393-6075

NEW LITERATURE

▼ SUPPLY REFERENCE COVERS SPECIFYING

The second edition of MicroENERGY's 32-page book, "Consider-



ations When Specifying Switchmode Power Supplies," is now available. The volume is packed with useful information on topics such as reliability, agency approvals, EMC, power-factor correction, specification writing, strife testing, custom versus

standard, vendor selection, thermal management, and power density. Appendices include major safety and quality agencies, and mechanical and electrical considerations.

MicroENERGY Inc.
745 E. State Rd. 434
Longwood, FL 32750-4909
(407) 831-2000
► CIRCLE 644

▼ BROCHURE DETAILS DESIGN SERVICES

Front-end simulation, analysis, design, and delivery of turnkey systems are described in Brochure No. 65953. This design service eliminates numerous prototype-design cycles to speed time to market and is supported by qualified interconnection-system engineers using state-of-the-art device and multi-line connector models. The service offers simulation, analysis, and fabrication of customer-proprietary systems operating at speeds from 1 MHz to 1 GHz and standard systems including Futurebus+, VMEbus, ISA/EISA buses,

and fast and wide SCSI.

AMP Inc.
P.O. Box 3608
Harrisburg, PA 17105-3608
(800) 522-6752
► CIRCLE 645

▼ CATALOG DESCRIBES INTERCONNECT LINE

A 200-page, full-line interconnection catalog contains full information on a large array of products. New products covered in Catalog No. 12 include sockets for relays, power modules, PLCs, LCCs, SOICs, and SOJs. Also offered are gull-wing DIP adapters for 0.050-in.-pitch devices, SMT single- and dual-row headers, high-density connectors, memory-card connectors, and more. Complete specifications and features are included for each product.

Advanced Interconnections
5 Energy Way
P.O. Box 1019
W. Warwick, RI 02893
(401) 823-5200
► CIRCLE 646



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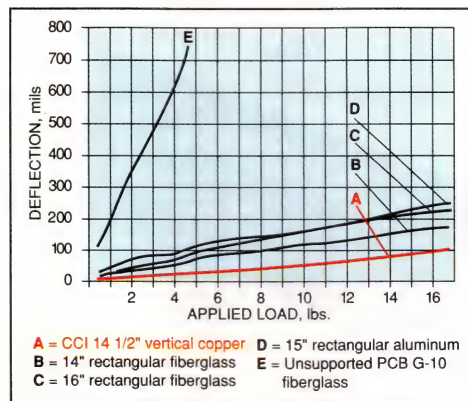


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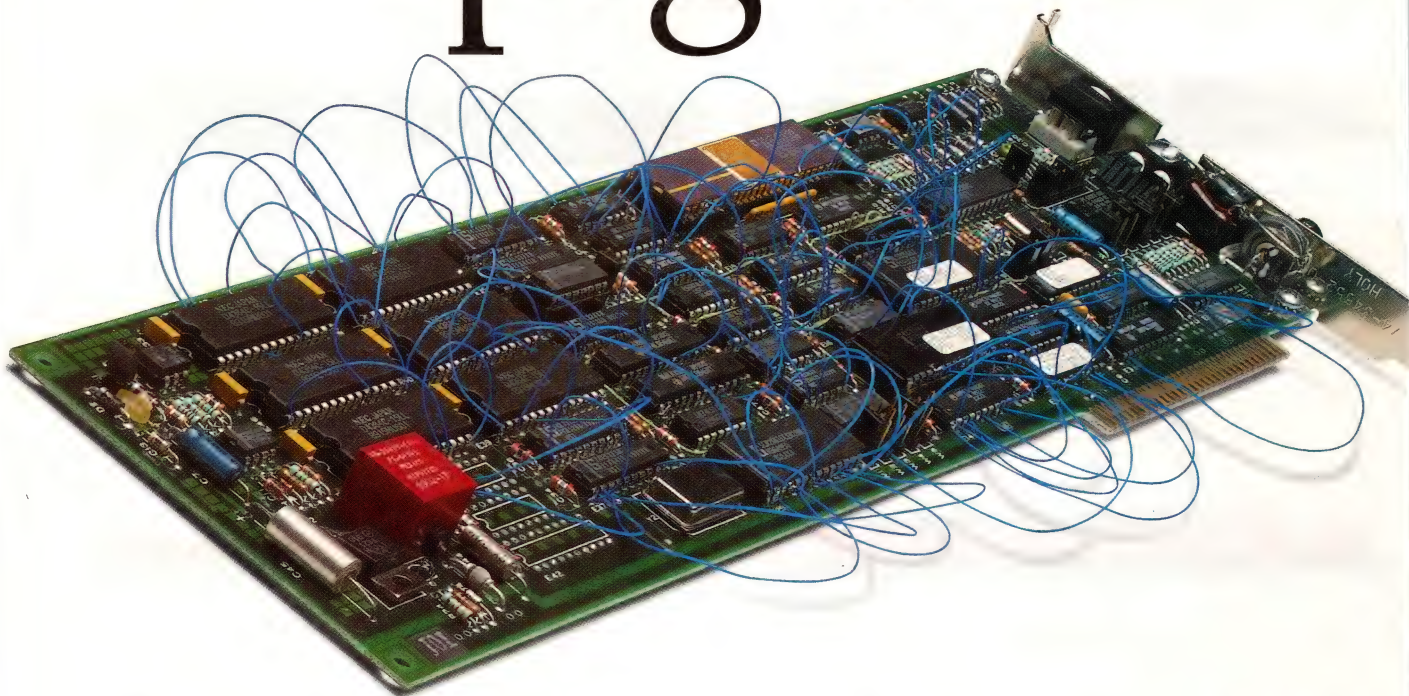
A comparison showing significantly better performance with CCI board stiffeners than with other conventional methods.

sensitive electronic components, as well as mechanical vibration shock absorbers. They'll even protect the PCB from cracks on solder joints and PCB traces. And the one-step installation requires no hardware. Send for a free applications bulletin to learn more.

CCI
Circuit Components Inc.

Circuit Components Inc., 2400 S. Roosevelt Street, Tempe, AZ 85282 • 602 967-0624 FAX 602 967-9385
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Hold The Spaghetti



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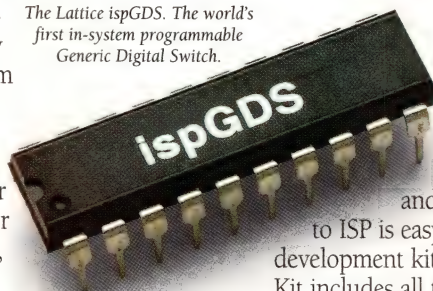


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NETWORKS AND INSTRUMENTATION.

DAVE BURSKY

The data rates employed by various high-speed data communications systems and network interfaces are forcing designers to look beyond CMOS and biCMOS solutions to deal with data recovery and routing. Systems operating at frequencies as low as 50 MHz often require that phase-locked loops (PLLs) run at ten times the system clock to provide wide lock-in ranges and minimal jitter.

For simple data-recovery circuits in systems that must clock data through at several hundred megabits per second to a few gigabits per second, 500-MHz on-chip operation is mandatory to push operating speeds well past the edge of most CMOS or biCMOS processes. Although there are skeptics, one alternative is the use of gallium arsenide (GaAs). In fact, the latest generations of GaAs-based circuits have come closer to the ideal solution than ever before.

By combining high-speed source-coupled FET logic (SCFL) and the slower but high-density direct-coupled FET logic (DCFL) on the same chip, designers at Vitesse Semiconductor developed a family of GaAs gate arrays optimized for high-speed data-communications and telecommunication applications. Close attention was paid to logic complexity, on-chip resources, and power levels so that the chips could be housed in low-cost, plastic, surface-mounted packages.

A SEA OF GATES

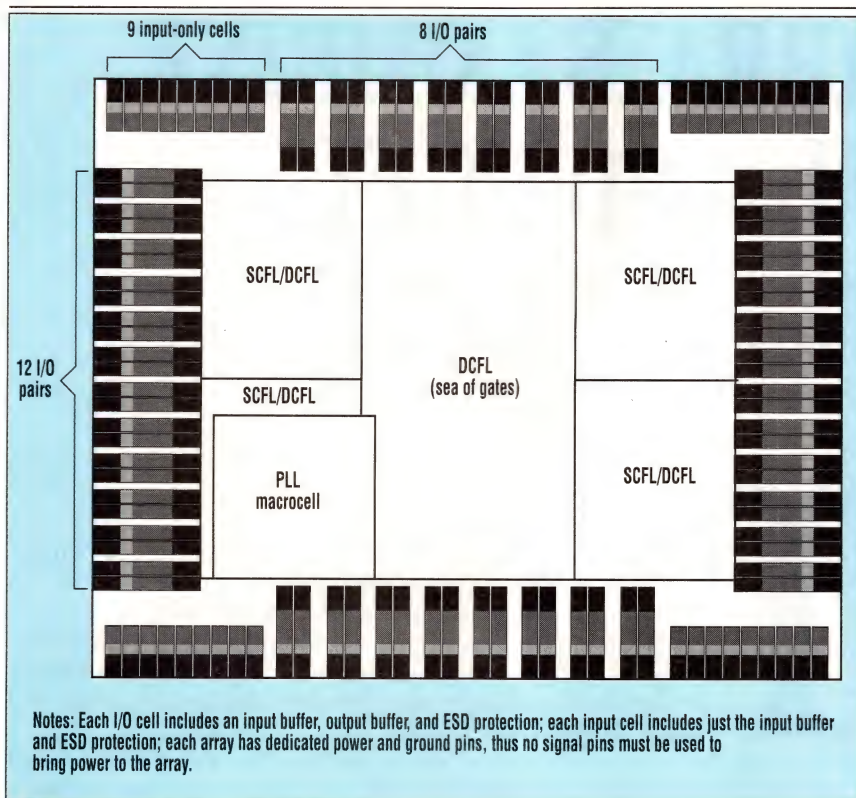
Members of Vitesse's SCFX array family will offer from 5000 to 30,000 total gates per chip, laid out in a channelless sea-of-gates architecture. Each array in the family contains a large block of DCFL gates, and on each of two opposing sides of the DCFL core are two blocks of gates that can be configured as either DCFL or SCFL gates (*see the figure*).

SCFL gates, which are well suited for high-speed operations, allow circuit functions such as D-type flip-flops to toggle at rates of more than 5 GHz. In addition, SCFL's differential-mode logic structure enables three-level series gating. However, their high performance comes at a price—power consumption per gate is quite steep, limiting the number of SCFL gates that can be used on a chip.

Using three-level series gating permits very efficient implementations of functions, such as 4:1 multiplexers, 2:1 multiplexer latches, and three-input XORs, while incurring just a single stage delay. A 4:1 multiplexer, for example, can operate at over 3 GHz while maintaining good waveform integrity. As a result, it meets the tough jitter requirements of telecommunications and data-communications applications, such as in Fibre Channel or Sonet interfaces.

DCFL gates, on the other hand, are better suited for high-gate-count logic circuits in which collective power dissipation is critical. For instance, an unloaded two-input NOR gate has a delay of just 37 ps while consuming a mere 0.2 mW, and a DCFL D-type flip-flop can toggle at rates above 1.6 GHz. Thus, complex, high-gate-count logic functions can be implemented with DCFL, and

COMMUNICATIONS GATE ARRAYS



BOTH DCFL AND SCFL circuits can be combined on one chip using Vitesse's SCFX family of GaAs gate arrays. DCFL gates are used in the core of the array. Blocks of gates on either side of the core can be configured as moderate-performance DCFL gates or high-speed SCFL gates. As a result, designers can optimize the use of both logic families to implement chips that deliver high performance but consume relatively little power.

the active power needn't be pushed much above 1 W or so. Furthermore, although DCFL-based logic can still perform at speeds of 1 GHz, it can be run slower using unbuffered gates. This conserves power in sections of the chip that are able to operate below full speed.

MIXING LOGIC

As is often the case, only small sections of a circuit must operate at very high speeds. Consequently, mixing the two logic types on the chip lets designers craft circuit functions to optimally match the an application's performance and power-consumption requirements. Moreover, custom masterslices can be created to optimize performance further by adding specialized megacells, such as blocks of static RAM, register files, or phase-locked loops.

Initially, Vitesse will offer two members in its SCFX family—the SCFX10K and the SCFX40K. The SCFX10K includes about 3000 usable DCFL gates in the array's core. In each

of the four SCFL/DCFL blocks, designers can implement either 24 SCFL gates or 576 DCFL gates (assuming approximately 50% gate utilization). In addition, the SCFX10K gate array has 67 signal pins: 27 input cells and 40 I/O cells.

The SCFX40K contains 10,000 usable DCFL gates in the core of the array. Each SCFL/DCFL block can be used to implement 99 SCFL gates or 2286 DCFL gates. Higher I/O pin counts also are available on the 40K chip—35 input cells and 80 I/O cells. Because both chips include abundant dedicated power and ground pads, designers can use all I/O pads solely for signal handling.

As an implementation test case, a 1.0625-Gbit/s transmitter and receiver were configured in a pair of SCFX10K arrays. The interface, which was designed to meet the ANSI X3T11 Fibre Channel standard, incorporates a low-jitter PLL for clock multiplication and clock recovery. TTL interfaces are used for parallel data input and output, and high-speed

differential inputs and outputs are employed for the serial data ports.

In the design, low-speed (53-MHz) logic was implemented with DCFL, while the 1.06-Gbit/s interface used SCFL. The transmitter required 57 SCFL cells, 31 I/O sites, 700 DCFL cells, and a PLL. The receiver needed 63 SCFL cells, 30 I/O sites, 950 DCFL cells, and a PLL. The transmitter chip consumes less than 1.5 W, while the receiver draws about 2 W. Those numbers are around 20 to 25% lower than a similar function implemented using a single logic structure.

Due to the channelless architecture of the arrays, the first layer of metal can be routed over unused cells, minimizing lost wiring channels and allowing the arrays to achieve about 50% utilization. The I/O buffers are compatible with standard TTL and ECL interface levels, and can be configured to offer low-voltage differential-swing signal levels.

The arrays in the SCFX family are based on the company's production-proven H-GaAs III process. The design libraries are supported on most popular design-automation platforms that run software tools from Mentor Graphics, Cadence Design Systems, Synopsys, and Viewlogic Systems, among others. Moreover, Vitesse has several proprietary tools optimized for the GaAs arrays that can dramatically improve the circuit-design process. One such tool is interactive graphical preplacement software that's supported in the X-windows environment. Macrocell libraries for the Motive timing verifier from Quad Design Technology also are available. □

PRICE AND AVAILABILITY

Design tool sets that capture SCFX designs are available immediately. Nonrecurring engineering charges start at \$35,000. Production pricing begins at between 0.6 to 0.8 cents per used gate for quantities of 1000 to 10,000 chips. The chips are housed in 100-lead PQFPs. Delivery is about eight weeks from finalization of the critical design review.

Vitesse Semiconductor Corp., 741 Calle Plano, Camarillo, CA 93012; Barry Sandefur, (805) 388-3700.

CIRCLE 511

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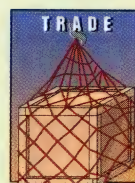
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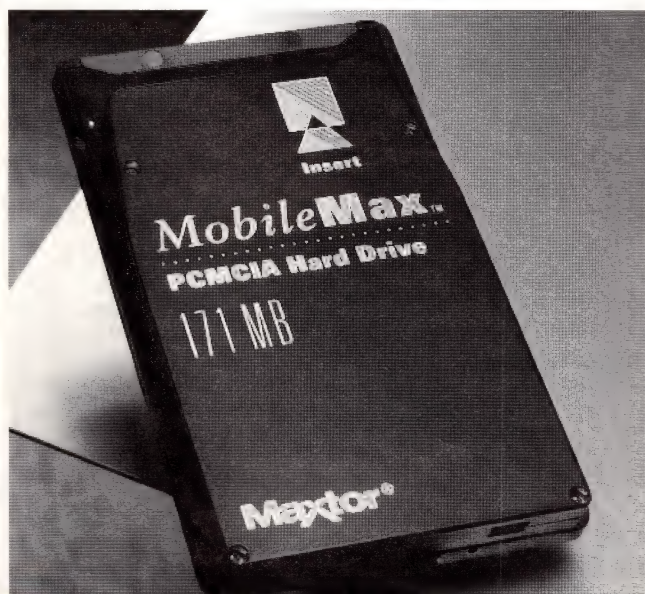
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DAVE BURSKY

DSP-BASED PCMCIA DISK DRIVE PACKS 171 MBYTES

A CUSTOMIZABLE 16-BIT
DSP CORE SERVES BOTH
AS A HIGH-ACCURACY
SERVO CONTROLLER AND
GENERAL-PURPOSE MCU.



1. THIS DISK DRIVE, the MobileMax 171 created jointly by Maxtor and Texas Instruments, packs 171 bytes into the same PCMCIA Type-III package as previous lower-density PCMCIA drives. The design employs a customized TI DSP core as the heart of a single chip that performs both digital servo control for head positioning and controls the host-to-drive interface.

As disk drives get physically smaller—dropping from 3.5 to 2.5 and even 1.8 in. and smaller in format—drive designers are hard-pressed to deliver high storage capacities, shorter access times, and lower power consumptions. One of the key concerns is the shrinking internal board space available for the control circuits, which has dropped by more than 60% from the 3.5- to 1.8-in. generations.

Within that shrinking space, designers typically must include a microcontroller, the read-channel electronics, the spindle control and read-write head-positioning control logic, and both a cache RAM and some firmware. One way to alleviate the problems caused by limited board space is to use higher levels of integration. However, as designers push to increase densities, head positioning to fit more tracks onto the small platter requires more complex control logic and precision servo control implemented with digital-signal processing.

Such advances are being seen in a new generation of 1.8-in. disk drives, including the MobileMax 171, a 171-Mbyte drive from Maxtor that fits in a PCMCIA Type-III physical form factor. It's able to fit in such a package thanks to a joint development effort between engineers at Maxtor, Longmont, Colo., and the customizable DSP (CDSP) product group at Texas Instruments Inc., Houston, Texas.

One key decision made by the design team, according to Curt Bruner, the 1.8-in.-drive lead-electronics engineer at Maxtor's Longmont facility, was to combine the DSP and MCU functions onto one 16-bit processor. However, rather than add some DSP functionality to an 8- or 16-bit microcontroller, the team opted for the reverse—they started with a 16-bit DSP core and incorporated controller functionality and about 9600 gates of interface logic. This approach delivers a high-performance DSP-based controller with new functionality, allowing designers to push beyond the 171-Mbyte generation and deliver even higher capacities in the same Type-III form factor.

The resulting drive performance includes a track-to-track seek time of 4 ms, an average seek time of 16 ms, and an average latency of 6.72 ms. Disks rotate at 4464 rpm and provide a data-transfer rate of 12.2 to 25.4 Mbits/s to or from the media. A 32-kbyte cache in the drive allows burst transfers on the host interface of up to 7.5 Mbytes/s (up to the depth of the cache) and a sustained data-transfer rate of up to 2.2 Mbytes/s (*Fig. 1*).

During spin-up, the drive draws 640 mA from a 5-V supply. While idling, the drive's current drain drops to 115 mA (575 mW with the 5-V supply). The drain falls to 15 mA in the standby mode, and down to 4 mA in the sleep mode. The DSP section will run at clock periods as short as 35 ns (instruction cycle at 5 V).

Weighing in at 65 grams, the drive can withstand operating shocks of up to 200 G and non-operating shocks up to 1000 G while delivering a mean-time-between-failure (MTBF) rate of more than 300,000 hours, and a start/stop cycle count exceeding 50,000. The drive also is very quiet—

HIGH-DENSITY PCMCIA DRIVE

only 25 dBA in idle mode.

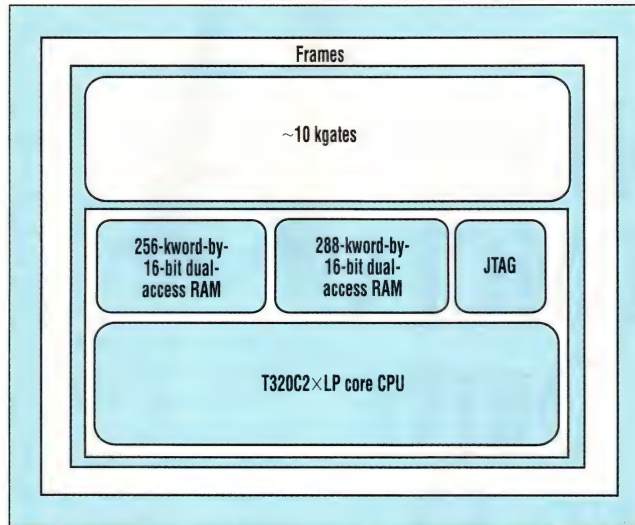
Not only will the DSP-based chip used in the MobileMax 171 serve as the basis for controlling higher-density drives, but the optimized 16-bit DSP core on that chip, according to Roger Peters, CDSP product manager at TI, will be available to anyone through TI's customizable DSP development channel.

With such potential, the chip can be used for more than just its DSP functions—it also can be the controller, eliminating the MCU altogether. However, existing DSP products in TI's library (the TMS320C5x, 320C25, etc.) were too costly—they carried many unneeded functions.

By opening up the design files on the TMS320C5x architecture, TI's designers were able to remove features that didn't relate to disk-drive control. They streamlined the core, reduced the chip's silicon area considerably, and preserved the main DSP execution pipeline. The result was the T320C2xLP, an area-efficient, 16-bit, DSP-core building block with 544 words of dual-access RAM (288 words of data RAM and 256 words that store either program or data) (Fig. 2).

In terms of functionality and performance, the core DSP engine in TI's TMS320C25 DSP IC is roughly the same as that in the T320C2xLP. However, because the T320C2xLP core is fabricated on a much newer but production-proven process (the same process used for the C5x family), it runs much faster. Part of the reason for the higher speed also stems from the core's simplicity. Since all other peripheral support functions were stripped off (including large memory blocks to hold the complex application programs), the DSP core is lightly loaded and thus is able to operate at very high speeds. ROM and more RAM can be added in 1-kword increments, either on-chip or off-chip. Internal control lines are configurable during chip design to define the memory configuration.

Logic functions were included for the disk control. Maxtor and TI implemented a servo demodulator (all tim-



2. THE STREAMLINED T320C2xLP CORE is a much-simplified version of the 320C5x 16-bit processor core. Designers removed all of the peripheral functions, except for the 544-word dual-access RAM, to streamline the core. A block of about 9600 gates also was added to implement the custom control logic that executes the spindle and read-write head-assembly control.

ing and control to handle the read channel and positioning) using about 9600 logic gates. More power management also was added through the use of the DSP circuit's processing power, instead of the conventional method of employing only hardware, leading to minimized silicon area. During prototyping, an off-chip flash memory to hold the firmware was connected to the address/data lines. In production, Maxtor expects to use a one-time programmable memory.

The cramped quarters of the 1.8-in. disk drive also makes the controller subassemblies difficult to test and troubleshoot. To ease these problems, both an emulation port and a full JTAG-compatible interface were included on the DSP/controller. The ports share the same I/O lines because the two functions complement each other. The disk drive's designers then could use the T320C2xLP serial JTAG interface to load data into the dual-access RAM and, in turn, exercise the T320C2xLP core.

Additional T320C2xLP test resources include a parallel signature analyzer and a cyclic-redundancy-check (CRC) checker so that full on-chip testing of the DSP core can be done via the JTAG port. As a result, the chip can provide a simple pass/fail test output. The parallel signature analyzer also lets the drive's design-

ers execute more system-level diagnostics both for manufacturing and possibly out in the field. For now, however, the diagnostic features are only available during disk-drive manufacture.

When the rest of the circuit design started to gel, one of the biggest challenges was the definition of the feature set incorporated by the chip. That's where the megacell flexibility of the TI gate-array design tools came into play, allowing the drive's designers to add logic, I/O functions, and memory.

In June 1993, when development really started rolling, engineers from TI "moved" into the Maxtor facility to help with the definition and design of the core. Late that year, the detailed engineering design

started in earnest, and thanks to the close working relationship of the two design teams, there were no miscommunications on the design data that had to be fed to the factory when the chip was ready for fabrication.

The combined use of the DSP engine core for both DSP and control applications was a learning experience for both Maxtor and TI designers—as they learned how to apply it, they started to see how the chip's horsepower can be exploited for even more functions that could be implemented with the DSP core. What that means is a further reduction of the component count inside the drive. □

PRICE AND AVAILABILITY

The MobileMax 171 Type-III form-factor PCMCIA disk drive lists for \$399 each in single-unit lots; production quantities will be available in the fourth quarter. Samples are available from stock. Contact Texas Instruments regarding the availability of, and ASIC development charges for, the T320C2xLP core.

Maxtor Inc., 211 River Oaks Pkwy., San Jose, CA 95134; John Hagerman, (408) 432-1700.

CIRCLE 511

Texas Instruments Inc., Semiconductor Group, Literature Response Center, P.O. Box 177228, Denver, CO 80217; (800) 477-8924, ext. 4500.

CIRCLE 513

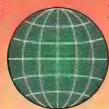
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MODERATELY
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PRODUCTS



NEWSLETTER

SCHEMATIC SYSTEM DOES TWO-WAY CROSS-PROBING

An enhanced version of the Pads-Logic schematic-capture tools from Pads Software Inc., Marlboro, Mass., is focused on providing engineers with a seamless design environment from design capture through board layout. The new version enables bidirectional cross-probing between the Pads-Logic schematic capture and the company's pc-board layout tools. In addition, Pads-Logic provides increased flexibility during schematic capture, including the ability to move parts into the layout tools with a simple click-and-drag; the ability to select components in Pads-Logic and use them to define component clusters in Pads' layout tools; and the ability to dynamically pass engineering change orders between schematic capture and layout. Pads-Logic is a multi-sheet schematic capture system that's fully integrated with the company's pc-board layout tools. Pads-Logic runs on PCs and workstations. It's available now for \$750. Call (508) 485-4300 for additional information. *LM*

CIRCLE 947

AUTOROUTERS RUN ON WINDOWS, NT PLATFORMS

The Specetra family of pc-board design tools from Cooper and Chyan Technology Inc., Cupertino, Calif., now runs under Windows and Windows NT. Regardless of platform, all products will support the same user interface and database. In other words, engineers can start their work on one platform and complete the job on another without any retraining or database conversion. The Specetra software includes placement, routing, and editing tools that use shape-based technology. The Windows 3.1 and Windows NT versions of the autorouting tool will be available in the third quarter. Pricing starts at \$3750. The Windows NT versions of the editing and placement tools will ship by the end of the year. Call (408) 366-6966 for more information. *LM*

CIRCLE 948

EM ANALYSES EXAMINE HIGH-FREQUENCY DESIGNS

HP-EEsof, Westlake Village, Calif., has bundled its Series IV Electromagnetic Test Bench with its standalone version of the HP Momentum planar electromagnetic simulator to provide quick EM analyses of high-frequency designs. Momentum is an EM simulator based on the method-of-moments circuit-analysis technique. It can analyze multilayer planar patterns under arbitrary, open-boundary conditions. At the same time, Electromagnetic Test Bench allows for fast EM analysis of circuit layouts using the same design information employed by the Series IV circuit simulators, without additional data entry. HP offers the standalone version of Momentum with links to the Electromagnetic Test Bench for \$32,000. The software runs on Unix workstations and personal computers. Future Momentum releases will incorporate Electromagnetic Test Bench features in phases. The first phase is expected in January 1995. For additional information, call the company at (818) 879-6200. *LM*

CIRCLE 949

INTELLIGENT DISPLAYS OFFER HIGH RELIABILITY

The Optoelectronics Division of Siemens Components, Cupertino, Calif., has announced the development of an innovative family of highly reliable light-emitting-diode programmable displays. The family includes three models: the IPD2555 (with a high-efficiency red LED), IPD2557 (with a high-efficiency green LED), and IPD2558 (with a yellow LED). All three are fabricated in a hermetically sealed, ceramic and glass package and incorporate an on-board CMOS drive with character-generating electronics. Each of the three programmable displays has four alphanumeric characters plus six LEDs.

Where conventional alphanumeric displays require an entire character position for decimal or degree indication, the LEDs in the intelligent displays provide increased functionality as separate decimal points or degree signs. Each 6.4-mm-high character is a 5-by-7 array of LEDs and can display any of the 96 ROM-resident letters, numbers, or symbols. The overall display dimension is approximately 12.45-mm high by 30.10-mm wide. The displays are stackable and operate from -55°C to +100°C at about 150 mA at the maximum brightness level. With these unique characteristics, the displays are ideal for applications that require decimal or degree signs to be used as indicators. Such applications will most likely focus on avionics and navigation, and include fuel-management and navigational-position displays. For further information, contact Rick Waltons-Smith at Siemens Components, (408) 725-3423. *CA*

CIRCLE 950

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WINDOWS NT PLATFORM HOLDS MULTIPLE MIPS CPUS

Multiple 64-bit R4400 RISC microprocessors, each running at 150 MHz, form the heart of the RISCstation 2000 workstation, from NEC Technologies Inc. The platform is designed to meet the needs of Windows NT and its associated applications. The Mips CPU is built with 32 kbytes of cache memory and contains 512 kbytes of secondary write-back cache on each CPU module.

The internal bus architecture, called MultiRISC, passes data at 400 Mbytes/s. The MultiRISC memory scheme enhances the bandwidth and integrity by interleaving the memory subsystem to access data in 128-bit-wide increments, and also by coding standard SIMMs to supply an error-correction capability. The memory subsystem resides in a daughterboard that supports up to

384 Mbytes of system RAM using 36-bit-wide, 70-ns SIMMs.

The RISCstation 2000 employs a 64-bit graphics interface that offers access to video RAM at the same speed as system RAM. Supported resolutions range from VGA to 1280 by 1024 pixels with 256 colors and a 60- or 72-Hz refresh. Available interfaces include one parallel and two serial ports, one SCSI-2 connector, and an Ethernet port.

Prices for the RISCstation 2000 are expected to range from \$6000 to \$10,000, depending on the processor configuration. That price includes 16 Mbytes of RAM, a NEC MultiSpin 3Xi CD-ROM drive, and the Windows NT operating system.

*NEC Technologies Inc., 1414 Massachusetts Ave., Boxborough, MA 01719; (508) 264-8000. **CIRCLE 670***

■ RICHARD NASS

CARD CONNECTS PC TO CELLULAR PHONE

Using a PCMCIA cellular direct modem, a portable computer, and a cellular phone, users can transmit and receive data. The modem card is called the Cellular Direct, and it plugs into a Type II PCMCIA socket at one end and a cellular phone at the other. Using integrated firmware, the card stores information about the phone so the modem can instantly recognize the phone upon power-up. This eliminates the need for an interface box and also eliminates the step of rebooting the computer. A proprietary technology improves the cellular data and fax throughput, regardless of the error-correction protocol used. The technique can also enhance existing cellular error-detection and correction methods by reducing the number of link-layer transmission errors. This should reduce the required number of retransmissions. Available now, the Cellular Direct PCMCIA modem sells for \$329. RN

*Apex Data Inc., 6624 Owens Dr., Pleasanton, CA 94588; (510) 416-5656. **CIRCLE 671***

BACKUP LAN SYSTEMS AT 94 MBYTES/MIN.

The ProLine CX QIC 10 backup and data-management system minimizes the time required to backup large Novell NetWare networks with transfer speeds as high as 94 Mbytes/min. through a SCSI-2 adapter. The system includes a quarter-inch cartridge (QIC) tape drive that holds 10 Gbytes of compressed data. The bundled software can send data to the tape drive from eight sources simultaneously. The combined transfer rates let the tape stream, thereby eliminating the starts and stops that can degrade performance. In addition to NetWare, the ProLine CX QIC 10 supports DOS, Windows, and OS/2. The system should sell for about \$1700. RN

*Tecmar Inc., 6225 Cochran Rd., Solon, OH 44139; (800) 624-8560 or (216) 349-0600. **CIRCLE 672***

PCMCIA-CARD DRIVE FITS DESKTOP PCs

The CardBay-AT drive makes it simple to embed a PCMCIA drive into a desktop computer. As an internal or

external unit, the drive holds up to four PCMCIA cards and mounts in a 3.5- or 5.25-in. disk drive bay. It supports Type I, II, or III cards and includes an on-board speaker for fax/modem applications. It can handle SRAM, flash, and ATA-flash cards; fax-modem, LAN, SCSI, and GPS cards; and ATA hard drives. Different socket configurations are available, ranging from one to four slots. One or two slots can stick out the rear of the computer, to plug into a network adapter or some other I/O device. That would leave the slots at the front of the machine available for cards that need to be accessed often, such as a storage device. Minimum system requirements include a 386-based PC, DOS 3.3, and Windows 3.0. Prices for the CardBay range from \$149 to \$209. RN

*Cardwell International Corp., 110 Blue Ravine Rd., Suite 156, Folsom, CA 95630; (916) 985-1880. **CIRCLE 673***

GRAPHICS SUBSYSTEMS WORK WITH IBM RS/6000

Users of IBM RS/6000 workstations can take advantage of the Freedom Series 6000 line of graphics accelerator subsystems. The family is based on Evans & Sutherland's Velocity technology and is available in three models with differing performance levels. At the high end, the Model 003 achieves up to 3.5 million vectors or triangular mesh polygons/s. The 3D graphics feature set includes hardware-accelerated texture mapping, antialiased lines, dots, and polygons, and transparency.

The IBM Freedom Series supports the OpenGL Application Programming Interface (API) and offers a high-performance, fully-featured graphics platform for applications that had previously been available only on Silicon Graphics workstations. Application availability will increase as software developers begin to incorporate the OpenGL API. The subsystem runs under the current version of AIX/6000 and is compatible with IBM's other OpenGL graphics accelerators. RN

*Evans & Sutherland Computer Corp., 580 Arapen Dr., P.O. Box 58700, Salt Lake City, UT 84158; (801) 582-5847. **CIRCLE 674***

TOOL DESIGNS BIST INTO ASIC RAM MEMORIES

A built-in self-test technology called RAMBIST offers comprehensive and efficient testing of ASIC RAM memory blocks. RAMBIST accounts for actual memory layout, allows at-speed testing, and accommodates embedded one- to six-port synchronous and asynchronous memory blocks in LSI Logic's 0.6- and 0.5- μ m, two- and four-layer-metal ASICs.

The technology is incorporated into the RAMBIST Builder tool, which works with the company's Verilog and VHDL design kits for the Concurrent Modular Design Environment (CMDE) back-end design verification system. RAMBIST, which is accessed through the MEMCOMP memory compiler, allows automatic integration of a test controller with ASIC memory blocks. When the completed chips are placed into test mode, these controllers exercise memory blocks by writing marching patterns, reading them back out, and reporting manufacturing defects. In production-test mode, RAMBIST controllers output a pass-fail signal. For detailed failure anal-

ysis, the debug-diagnostic mode shifts out the contents of the memory as a failing address. After BIST operations, users can clear the memory contents. The technology is recommended for 16-kbit and larger memory blocks. For a typical 16-kbit block, RAMBIST adds about 6% to the silicon area.

RAMIST uncovers stuck-at, transition, coupling (transitions causing data errors in nearby cells), and timing errors. One controller can be shared among multiple identically configured memories on each ASIC. Because only a few signals per controller are needed, the technology imposes minimum routing overhead. The result is a minimum impact on overall chip routability.

The RAMBIST technology will be available to CMDE users at LSI Logic Design Centers this fall. Full integration with Verilog is scheduled for the fourth quarter of 1994, and with the VHDL design kit for the first quarter of 1995.

LSI Logic Corp., MS-D102, 1551 McCarthy Blvd., Milpitas, CA 95035. CIRCLE 675

■ JOHN NOVELLINO

allel load capability for Verilog simulations. The interface, a companion to the existing serial Verilog interface, improves performance by several orders of magnitude in the vector sign-off process for full and partial scan. The second new interface is the industry-standard Summit Design Inc. (formerly TSSI) WGL vector format, which offers direct paths to test equipment with proven transition paths.

TestGen 2.0 prices begin at \$75,000. The Start module, including LITE, costs \$25,000.

Sunrise Test Systems, 2730 San Tomas Expressway, Suite 200, Santa Clara, CA 95051; (408) 980-7600. CIRCLE 676

■ JOHN NOVELLINO

NETWORK ANALYZER HAS VERY FAST SWEEP RATE

A pair of vector network analyzers offers users extremely fast sweep rates. The R3752A, which is suited for integration into ATE systems, has a 32-by-8-character fluorescent information display. The R3753A is designed to operate as a standalone instrument. It has a high-resolution, 7.8-in. thin-film transistor color LCD display. The 500-MHz instruments have a sweep rate of 0.1-ms/point at

TOOL PICKS, IMPLEMENTS BEST TEST LOGIC METHODS

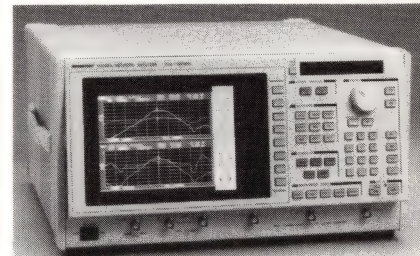
An automatic test-pattern-generation software package, TestGen Version 2.0 offers major improvements over Version 1.2. Besides enhancements in full-scan performance, IEEE-1149.1 support, new vector interfaces, and other features, users can opt for the Low-Impact Testability Enhancement (LITE) tool, which is part of the Sunrise Testability Analysis and Rule-checking Tool (Start).

Using proprietary test-optimized algorithms, LITE automatically selects and implements the most cost-effective test methodologies for different portions of a complex circuit design in one pass through the circuit. The software may choose full scan for some parts of the chip, par-

tial scan for other modules, and non-scan design-for-test techniques for areas where scan is not possible. LITE takes advantage of functional vectors to guide the selection of test-logic insertion, under complete user control.

Version 2.0 also includes IEEE-1149.1 (boundary-scan) verification testing. Automatic functional verification of the required 1149.1 operations assures users that their boundary-scan design is correct. The test vectors generated create high fault coverage. Also, the software supports and integrated boundary-scan and internal-scan architecture. Multiple independent scan chains can be used effectively with the 1149.1 design.

One new vector interface is a par-



a 10-kHz resolution bandwidth, and a blanking time of 5 ms.

The units have three input channels that allow two components of the same type to be tested simultaneously. Both come with a 3.5-in. disk drive, and RS-232C, 8-bit parallel, and IEEE-488 interfaces. The instruments are made by Advantest and sold in North America through Tektronix. The R3752A costs \$19,900, and the R3753A cost \$23,500. Delivery is in 10 weeks. JN

Tektronix Inc., Test & Measurement Group, P. O. Box 1520, Pittsfield, MA 01202; (800) 426-2200. CIRCLE 677

NEW PRODUCTS

INSTRUMENTS

12-BIT CARD DIGITIZES AT 60-MSAMPLE/S

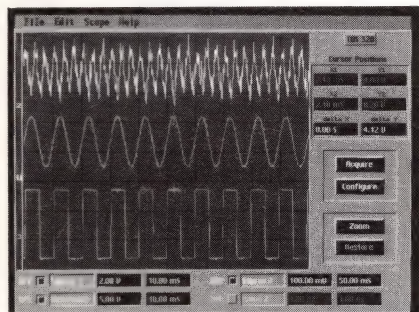
The CompuScope 6012 is an IBM PC/AT-compatible plug-in card that performs 12-bit analog-to-digital conversion at sampling rates to 60 Msamples/s on one channel, and 30 Msamples/s on two channels. The card features a signal-to-noise ratio of 62 dB and a total harmonic distortion of -61 dB, measured at the maximum sampling rate. Because the card's sample rate is faster than the ISA bus can handle, data is stored in an on-board memory. The initial offering includes 512 ksamples of SRAM, but has 8-Msamples addressability. Up to eight cards can be connected together with a common clock and trigger. Included is the GageScope software, which allows users to operate the card like an oscilloscope without doing any programming. The CompuScope 6012 costs \$6995. JN

Gage Applied Sciences Inc., 5465 Vanden Abeele, Montreal, Quebec, Canada H4S 1S1; (800) 567-4243 or (514) 337-6893. CIRCLE 678

SOFTWARE SENDS DSO WAVEFORMS TO A PC

DocuWave is an executable software application that acquires waveforms from any Tektronix digital oscilloscope and exports them to other applications for documentation and publishing uses.

The software works with any DOS



PC and can run as a DOS application under Windows. Components of DocuWave include the National Instruments LabWindows instrumentation software and IEEE-488 plug-in hardware.

The DocuWave software can acquire up to four waveforms simultaneously and generate TIFF, BMP, PCX, HPGL, and EPS images of them. After the waveforms are ac-

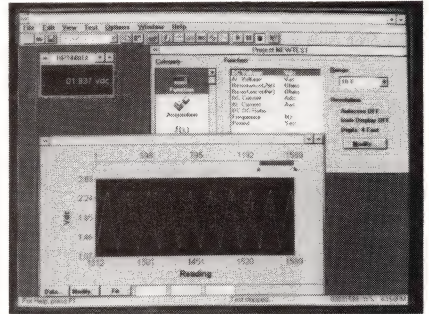
quired by the PC, users can zoom, adjust, and document them on the computer screen. DocuWave costs \$195 for the software only. It is also offered bundled with a National Instruments IEEE-488 board and oscilloscope. JN

Tektronix Inc., Test and Measurement Group, P. O. Box 1520, Pittsfield, MA 01202; (800) 426-2200. CIRCLE 679

SOFTWARE SENDS DMM, COUNTER DATA TO PC

The Hewlett-Packard 34812A BenchLink/Meter software allows users to transfer data from HP digital multimeters and counters to a personal computer without having to write computer code. The Windows-based software also solves connectivity problems and simplifies data analysis.

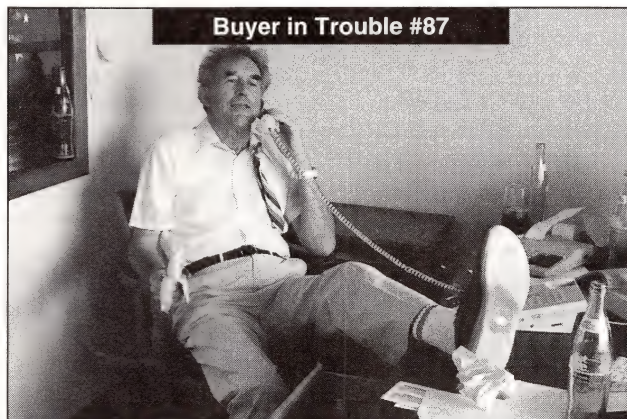
Incoming data can be displayed on the computer's screen in real time as scrolling strip charts. Users can analyze the captured data using graphs,



histograms, and statistical tools.

The software operates over an IEEE-488 or RS-232 interface and supports Hewlett-Packard or National Instruments IEEE-488 interface cards. In addition to test type, number of measurements, and test intervals, users can select speed and accuracy options and define test limits. The HP 34812A BenchLink/Meter software costs \$150. JN

Hewlett-Packard Co., Direct Marketing Org., P. O. Box 58059, MS51L-SJ, Santa Clara, CA 95051-8059; (800) 452-4844. CIRCLE 680



Plan It of the Apes

"Howard, my boss, said I was dumber than an orangutan for buying 400,000 transformers from offshore instead of calling Prem. He said Prem has no minimum order quantity and you can schedule deliveries when you need them. He threatened to let scientists dissect me to see if I'm the missing link.

I really shoulda called Prem.

You oughta call Prem!"



Where Quality Really Counts!

For Prem's new catalog or additional product information, call or write
Prem Magnetics, Inc.
3521 North Chapel Hill Road, McHenry, IL 60050.
Phone: 815-385-2700. FAX: 815-385-8578.

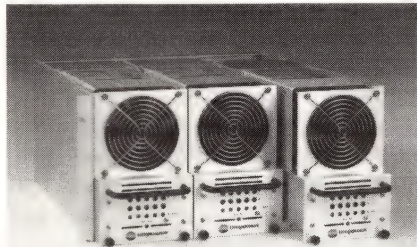
READER SERVICE 106

NEW PRODUCTS

POWER

HOT-PLUG SUPPLIES BOAST REDUNDANCY

A hot-plug power system is available to produce 2400 W of output in a 2 + 1 redundant configuration. The THN Series consists of three hot-plug power units in a 19-in. rack assembly that is 8.75 in. high by 19 in. wide by 17 in. deep. Each power unit delivers up to 1200 W of output, has integral isolation diodes on the output and



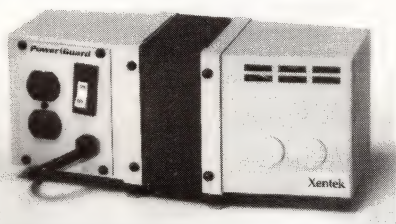
self-contained fan cooling, and is quickly replaced while the system continues to generate full output. For non-redundant operation, the system produces up to 3600 W of output. The power units have current-sharing circuitry that automatically equalizes output currents with all outputs connected in parallel. Up to four outputs are available with a choice of voltages from 2 to 48 V dc. Power-unit prices start at \$1765 each, with 100-piece prices at \$1331. The corresponding chassis prices are \$550 and \$415. Delivery is in eight to 10 weeks. DM

Unipower Corp., 3900 Coral Ridge Dr., Coral Springs, FL 33065; Warren Peters, (305) 346-2442.

CIRCLE 681

ISOLATION TRANSFORMERS HOLD OFF TRANSIENTS

Reliable, cost-effective elimination



of voltage transients, noise, and ground-loop problems is provided by the PowerGuard series of extreme-isolation transformers and power-line conditioners. The units feature the company's Advanced Resonant Magnetics wide-bandwidth filtration

circuitry, which provides attenuation of "real-world" common-mode and transverse-mode noise not addressed by the narrowly defined ANSI/IEEE C62.41-1980 waveforms. Pricing starts at \$305 for single-phase units and \$1947 for three-phase units. Delivery is from stock for single-phase types and in four to six weeks for three-phase models. DM

Xentek Inc., 1770 La Costa Meadows Dr., San Marcos, CA 92069; Charles Henry, (619) 471-4001. CIRCLE 682

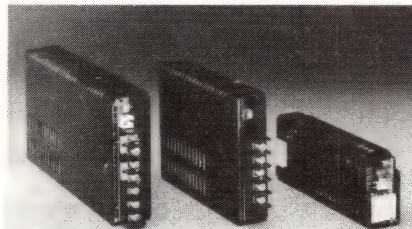
1200-V, 70-A IGBT SAVES PC-BOARD SPACE

Reducing the traditional amount of space consumed by IGBT modules, the model IXSK35N120AU1 module mounts vertically to take up less than 1 in.². The module consists of the company's 70-A, short-circuit-rated IGBT and a fast-recovery epitaxial diode, both in a three-leaded TO-264 package. The module is rated at a minimum blocking voltage of 1200 V with a maximum saturation voltage of 4 V and typical switching fall time of 700 ns. Applications include ac-motor speed controls, uninterruptible power supplies, dc servo and robotic drives, and dc choppers. Pricing in lots of 1000 is \$16.50. Samples are available now and production quantities will ship in the October/November time frame. DM

IXYS Corp., 3540 Bassett St., Santa Clara, CA 95054; (408) 982-0700. CIRCLE 683

SMALL SWITCHERS DELIVER EFFICIENCY

With reductions in the number and size of components required, the HY



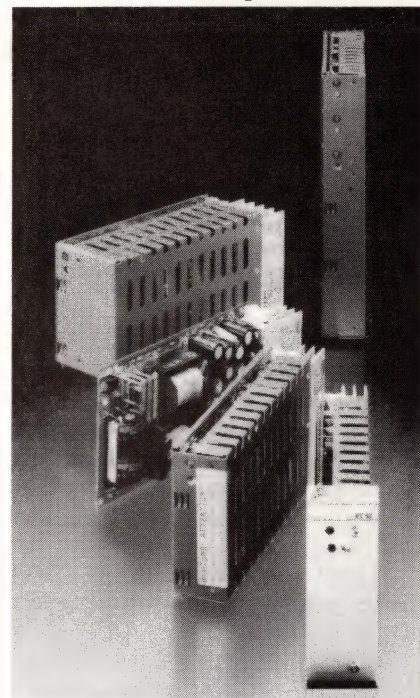
Series of switching power supplies represent a compact, lightweight, and highly efficient answer to power-supply requirements. The units offer a profile of less than 1 in. and efficiency ratings ranging from 77%

to 85%, depending on power level and output voltage. The series offers 25-, 50-, and 100-W models, each with 5-, 12-, or 24-V outputs. All have universal inputs and meet IEC950, UL1950, and CSA22.2/154 specs. Overload and overvoltage protection is included, as is remote sense and remote on/off in the 100-W model. Call for pricing and delivery. DM

Shindengen America Inc., 2985 E. Hillcrest Dr., Suite 140, Westlake Village, CA 91362; (800) 634-3654. CIRCLE 684

MODULAR SUPPLIES PLUG INTO CARD CAGES

The EC Series of 19-in. modular plug-in ac-dc converters provides a low-



cost supply without compromising on thermal management, conducted noise, performance, or safety in 19-in. card-cage applications. Models include the Monovolt EC 50, a primary switched-mode, 50-W supply with power-fail function and rear heat sinks. Four power options are available: 5, 12, 15, and 24 V. A triple-output version, the Trivolt EC 50, is also offered, as is a 100-W model and a 125-W triple-output type. Pricing for a Monovolt EC 50 supply is \$244. Delivery is from stock. DM

VERO Electronics Inc., 1000 Sherman Ave., Hamden, CT 06514-1336; George Ross, (800) 242-2863. CIRCLE 685

PIZZA-SIZE ATM-DEVELOPMENT PLATFORM OFFERS TASTY "FREE TOPPINGS" TO SPEED APPLICATIONS TO MARKET

Help is on the way for the pioneering technologists who are bravely designing ATM transceivers, switches, and routers in the face of incomplete and still-evolving standards. Arriving in the form of a powerful, real-time development and performance-analysis system, the pizza-box-sized unit sports two RISC engines and comes complete with a full software suite tailored specifically for ATM applications. Offered by LSI Logic, Milpitas, Calif., the ATMizer R/T is a prototyping system that furnishes tools for the development of hardware, software, and applications based on the ATMizer CPU, LSI's programmable ATM processing engine.

Co-developed with Newbridge Networks, SynOptics, and Ascom Tech, the ATMizer is a single-chip ATM engine that's based on the architecture of LSI's popular MIPS R3000 RISC CPU. The ATMizer may be used as a standalone chip or incorporated as a standard logic core for development of custom ATM ASICs. Designed specifically for crunching ATM cells, the 32-bit RISC processor is capable of supporting all established ATM adaptation layers and can process up to 64,000 virtual channels (VCs) of voice, video, and data simultaneously. Thanks to its efficient architecture, it is also capable of handling software intensive, higher-level tasks, such as LAN emulation and congestion management. Part of the ATMizer's success is due to its reprogrammability, which allows products to keep up with evolving ATM standards through simple software upgrades.

By putting the ATMizer on a prototyping card (complete with ROM-based monitor/debugger, program and data RAM, two serial-communication ports, and a UTOPIA-compliant PHY-layer ATM interface), LSI Logic created a practical, flexible development tool. The ATMizer R/T platform contains two of these boards, one serving as the SAR engine board, operating at up to 155 Mbits/s, while the other board func-

tions as a host CPU. The host board is responsible for building protocol data units (PDUs), and for providing the necessary messaging and interrupt mechanisms for the SAR engine. Application code may be written and compiled on most workstations and then downloaded to either board via their serial ports.

The board also features a VL-bus (VESA local-bus) architecture common to many 486-based computers. This host interface serves as a means of easily integrating the development card with a prototype host system. In addition, it provides a reference hardware design for network interface card (NIC) manufacturers.

Originally produced to support LSI's internal development efforts, the R/T platform comes with a full compliment of software. Besides the on-board monitor/debug program, LSI supplies royalty-free source code listings of its AAL5 SAR software. Also included are code and code listings for the host interface and performance-monitoring software. Most of the software is written in C and may be used in whole or part without any additional fee.

Further support for ATMizer code development will come from Algorithmics Ltd., London, England, in the form of licensed cross-tools for use with the R/T platform. Algorithmics offers compilers, assemblers, linkers, and debuggers for MIPS-based processors, available in packages that run on most popular workstations. Like the PROM and SAR source code, the cross-tools may be used without paying royalties. "The alliance with Algorithmics will enable our customers to immediately begin developing code for their ATM-based hubs, routers, and NICs," says Arvind Kumar, marketing director for networking platforms in LSI Logic's Telecom Products Division.

The ATMizer R/T platform enables ATM product designers to evaluate the functions and performance (up to 155 Mbits/s) of the ATMizer architecture, and emulate future system performance. It offers

the unique opportunity to develop both the host and ATM adaption software on one system, using the same tools, and even serves as a real-time monitor for an existing ATM network. Used this way, it can monitor an ATM data stream and provide performance and statistical data for individual channels.

By putting R/T's SAR board in loopback mode, designers can use the board's PROM-based monitor to develop, test, and debug code independent of a specific physical ATM transmission medium. With an optional UTOPIA-compliant framer module attached, the R/T platform will emulate the system performance of various physical media, such as unshielded twisted pair and optical fiber. Initial framer modules are available to support the 100-Mbits/s 4B/5B, the 51-Mbits/s STS1, the 155-Mbits/s SONET/STS-3C, the 45-Mbits/s DS3 ISDN, and the 25.6-Mbits/s data stream transmitted over cat-3 UTP. For complete ATM network emulation, the designer can connect two ATMizer R/T platforms together using the appropriate physical media and framer modules.

"Now that most of the basic PHY layer issues are solved, our development platform will enable designers to tackle the next class of problems facing ATM," says Tony Stelliga, vice president and general manager of the Telecom Division at LSI Logic. Stelliga indicated that several customers were already using the ATMizer R/T system to look at the problems involved with signalling over WANs, LAN emulation, traffic control, congestion management, and MPEG video transport.

Pricing for a typical configuration of the ATMizer R/T starts at \$15,000. Prices for individual framer modules begin at \$2000 each. Platforms are available from stock, with delivery in four weeks.

LSI Logic Corporation, Literature Distribution Dept., MS D102, 1551 McCarthy Blvd, Milpitas, CA 95035; (408) 433-8000. CIRCLE 686

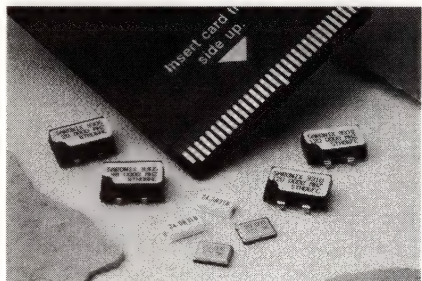
■ **LEE GOLDBERG**

NEW PRODUCTS

COMPONENTS

MINI SMT OSCILLATORS CUT INSTALLED COSTS

In addition to providing a wide range of output frequencies, the SMT S1600/S1650 oscillators feature plastic and ceramic packaging for lower manufacturing costs and improved end-product quality. The oscillators are available in frequencies from 1.5 to 80 MHz and are well suited for fre-



quency generation and control in PCMCIA, telecom, instrumentation, and computer-system designs. Outputs are compatible with both HCMOS and TTL and can drive up to five TTL loads. The S1650 drives up to 50 pF and includes the tri-state function. Pricing ranges from \$6.80 to \$9 in lots of 100. DM

SaRonix, 151 Laura Lane, Palo Alto, CA 94303; (800) 227-8974. CIRCLE 687

SCSI TERMINATOR EASES BUS DISCONNECTS

With on-chip resistors and a 2.9-V regulator, the REG5601 is an 18-line active terminator that meets all



SCSI-2 requirements by providing the prescribed 110-Ω termination for low power dissipation and high-speed data transmission. The device is an alternate source for the 5601 SCSI terminator. It can be disconnected from the bus with a single logic-control line. Output lines retain high impedance without power applied. Each data line is individually clamped to ground to dissipate negative-going glitches. Key specs in-

clude a 2.9-V current-limited and thermally protected regulator, a power-down mode of 150 μ A maximum, and an output capacitance in disconnect mode of 10 pF typical. The device comes in a 28-lead SMT package for operation from zero to 70°C. Pricing is \$4.60 in lots of 10,000 with delivery from stock. DM

Burr-Brown Corp., P.O. Box 11400, Tucson, AZ 85734; Bonnie Baker, (800) 548-6132. CIRCLE 688

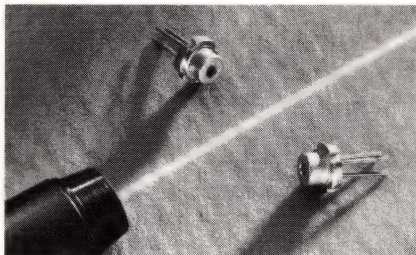
TUBEAXIAL FAN COOLS EFFICIENTLY

A high-reliability, military-grade tubeaxial fan is available for air-cooling of electronic equipment. The IM-Cool 400 fan offers a footprint of only 3.75 in. in diameter, 2 in. of axial depth, and weighs 1 lb. Tubeaxial technology delivers a directed flow of air and can be used in either a blow-through or draw-through mode. Air delivery is rated at 190 cfm (free air) when operating at 11,000 rpm. The unit may be operated from either 115 or 200 V ac, 50/60 or 400 Hz. It meets or exceeds the requirements of MIL-B-23071 and other applicable military standards. Call for pricing and delivery. DM

IMC Magnetics Corp., 475 Wireless Blvd., Hauppauge, NY 11788-3951; Otto Loorents, (516) 231-8100. CIRCLE 689

VISIBLE LASER DIODES CONSUME LITTLE POWER

Two 5-mW microminiature laser diodes emit visible light and offer low power consumption for uses in bar-



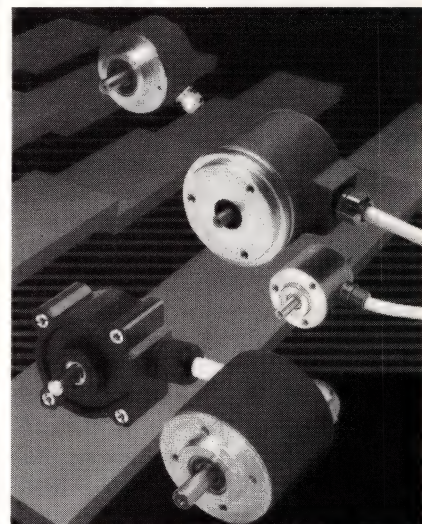
code scanners and laser pointers. The two red-light diodes include the higher-reliability model SLD1121VS for scanners and the lower-cost SLD1122VS for pointers. Both are available in 5.6-mm flat-top packages. The 670-nm devices have a recommended radiant output power of 3 mW, a low threshold current of 40 mA typical, and 5 mW of optical out-

put power. At a 3-mW radiant output, operating current is 50 mA and voltage is 2.5 V. Production quantities are priced at \$15 for the SLD1121VS and \$14 for the SLD1122VS. Both are available from stock. DM

Sony Electronics Inc., Component Products Co., 3300 Zanker Rd., San Jose, CA 95134; (408) 432-0190. CIRCLE 690

PRECISION ENCODERS SOUND SAFETY ALARMS

In the event of undervoltage, dirt accumulation, short circuit, overheating, or disk breakage, Bourns's line of opto-ASIC-chip-based encoders send out an error message that can be used to deactivate systems and avoid damage to the encoder and the system itself. Both incremental and absolute encoders are offered. Models BI31, BI32, and BI39 are incremental types ranging in size from 30



to 39 by 39 mm with shaft diameters of 5 and 6 mm and maximum speeds of 4000 and 6000 rpm. Incremental types include models BI30, BI36, BI58, and BI58H. Their shaft diameters range from 5 to 12 mm with maximum speeds of 10,000 and 3000 rpm, respectively. The BA58 absolute shaft encoder, single- or multi-turn, has a shaft diameter of 6 or 10 mm with maximum speed of 6000 rpm continuous duty. Call for pricing and delivery. DM

Bourns Inc., Integrated Technologies Div., Sensors/Controls Products, 2533 North 1500 West, Ogden, UT 84404; Blair Larsen, (801) 786-6367. CIRCLE 691

POPULAR PC-BASED DESIGN ENVIRONMENT MOVES TO THE WINDOWS OPERATING SYSTEM

OrCAD is moving its next-generation product line, called OrCAD Design Desktop, to the Windows operating system. Existing OrCAD products run under DOS. The first Desktop product to be made available will be OrCAD Capture for Windows, a design-entry toolset written specifically for Microsoft Windows.

The design-capture program exploits the Windows-based interface and well-established protocols for sharing information with other Windows applications. It's created with the Win 32s API, C++, and Microsoft Foundation Classes technology. The result is that OrCAD Capture will run fast on all Windows plat-

forms, and will provide an easy path to integrate emerging Windows technology being developed by Microsoft, including Object Linking and Embedding (OLE).

OrCAD Capture for Windows is data-compatible with the company's DOS-based predecessors. However, it delivers enhanced capabilities in three major areas: user interface, database, and utilities. Its Windows interface supports point-and-click selection and editing of objects.

The new object-oriented database supports user-defined properties. It also facilitates back-annotation from physical-layout and -analysis tools. The database is electrically intelligent, which enables automatic junctioning, on-line verification of con-

nectivity, and the ability to highlight a net across schematic pages.

All the utilities in OrCAD Capture are on-line. Users can have a schematic window and a part window open at the same time. Commands are context-sensitive, so the application menu understands what users are editing and makes the appropriate commands available.

OrCAD Capture for Windows will be available by the end of November. Pricing is set at \$995. Other products in the OrCAD Design Desktop line are under development, and will be introduced by the end of the year.

OrCAD, 9300 S.W. Nimbus Ave., Beaverton, OR 97005-7137; (503) 671-9500. CIRCLE 692

■ LISA MALINIAC

BOARD-DESIGN SYSTEM TARGETS USERS' NEEDS

Release 8.0 of Cadence's Allegro Correct-By-Design (CBD) pc-board design system targets users' requirements with new levels of openness, productivity, and performance. Allegro 8.0 offers extendibility in pc-board design through Skill, the company's programming language that lets users customize their design environment. Users can accelerate design throughput with Allegro's programmable design flows, etch-editing capabilities, and support for the latest in raster photoplotting. A semi-automatic route editor lets users perform interactive design with features such as route-to-cursor, which routes a connection from a selected point to the current cursor location. Overall system speed has been increased with faster design-rule checking and push-button integration of the Cadence Prance-XL autorouter. Allegro CBD is available in configurations aimed at design engineers, layout designers, and physical-packaging experts. Pricing ranges from \$33,000 to \$109,000. The optional Skill Developer's Kit costs \$15,000. LM

Cadence Design Systems Inc., 555 River Oaks Pkwy., San Jose, CA 95134; (408) 943-1234. CIRCLE 693

LIBRARIES SUPPORT SUBMICRON PROCESSES

The libraries from VLSI Libraries are now optimized for submicron CMOS processes down to 0.35 μm . Standard products from VLSI Libraries include a wide selection of standard cells; single-, dual-, and multi-port RAMs; ROMs; multipliers; datapath elements; I/O cells; and many other macrofunctions. The libraries are designed for density and performance, and operate at frequencies in excess of 100 MHz. All products are delivered completely integrated into existing EDA tools. A full set of standard cells is available. The cells are optimized for the target process and the place-and-route tool. RAMs and ROMs can be ordered in a wide variety of sizes and speeds. The multipliers and datapath elements are designed to be used in high-performance math, graphic, and digital-signal-processing applications. Library elements and generators can be purchased individually. Block instances and standard cells, optimized for a specific process, can be delivered in eight to ten weeks. Call the company for pricing and additional product information. LM

VLSI Libraries Inc., 3135 Kifer Rd., Suite 101, Santa Clara, CA 95051; (408) 986-9300. CIRCLE 694

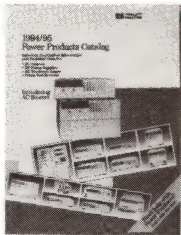
LIBRARY HELPS MODEL HIGH-SPEED DESIGNS

The MasterModel Digital Logic Library from Zeelan Technology contains more than 2500 models for high-speed parts from semiconductor companies like Motorola, TI, and Toshiba. Logic families covered by the Digital Logic Library include ABT, AC, ACQ, BCT, LS, and standard TTL, among others. In addition, the company has libraries for the PowerPC, 80486, 68040, and Pentium line of microprocessors. Zeelan's model libraries are generated using a proprietary technology integrating stimulus and acquisition hardware with model-extraction software to capture critical device characteristics. Each measurement-based model is specific to the semiconductor manufacturer, digital logic family, part number, and version. All models include the pin outs and pin names. The resulting libraries are formatted to match specific simulator requirements, and are ready to load and run without additional effort from users. Call the company for pricing and additional information. LM

Zeelan Technology Inc., 10550 S.W. Allen Blvd., Suite 108, Beaverton, OR 97005; (503) 520-1000. CIRCLE 695

POWER PRODUCTS AND AC SOURCES

Hewlett-Packard, Palo Alto, Calif., has published its 1994/95 *Power Products Catalog* (literature 5091-9593EUS), which provides application information and product specifications for its power-product-line users worldwide. This 66-page edition provides the latest technical information for ac sources, dc power supplies, dc electronic loads, power test systems, and solar-array simulators. CM **CIRCLE 930**



PGA FAMILY OF TEST, BURN-IN SOCKETS

A free eight-page brochure describing a complete family of Textool PGA test and burn-in sockets and accessories is available from 3M Electronic Products Division, Cedar Rapids, Iowa. The brochure details a comprehensive line of PGA sockets for virtually any pin count and lead configuration. A unique feature of the literature is a one-page work sheet that allows engineers to design their own socket layout for production. The four-color brochure includes color photographs, product information, and specifications on the Grid ZIP sockets, Carrier Compatible sockets, Interstitial Sockets, PGA receptacles, and Grid ZIP kits (sockets for smaller test applications). The sockets are available in either PES or high-temperature Torton. CM **CIRCLE 931**

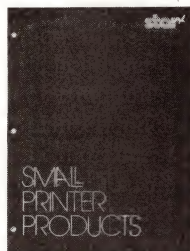
DISK HELPS CREATE DATA-ACQUISITION SYSTEM

The DAQ Designer interactive data-acquisition planner from National Instruments, Austin, Texas, was updated to include a number of new products from the company. The disk-based software helps users configure systems for PC/XT/AT/EISA and Micro Channel-based computers. Through its graphical interface, DAQ Designer asks the developer questions about system requirements, such as the type and number of analog and digital signals, the type and number of sensors

and signals, and signal conditioning needs. The program analyzes the answers and recommends specific plug-in boards, conditioning products, cable assemblies, and software packages. After the user has selected the products, DAQ Designer creates a summary list that can be stored or printed. JN **CIRCLE 932**

SMALL PRINTER PRODUCTS BROCHURE

Star Micronics America, Piscataway, N.J., has released its 1994 small printer products catalog. The 26-page color brochure details the company's full line of printer products, ranging from 22 to 44 columns. Highlighted are the newest housed units and printer mechanisms. The brochure describes the pertinent functions of standalone printers, printer mechanisms, control boards, and accessories. Information on applications, printing speed, dimensions, and different character types are included. In addition, the catalog contains specification charts, print samples, and full color photographs of all the products. The catalog is free. CM **CIRCLE 933**



STANDARD AND CUSTOM INTERCONNECT SOLUTIONS

A free short-form catalog from Aries Electronics, Frenchtown, N.J., features a wide range of standard and custom products for solving interconnection and packaging problems. Included in the 16-page *Interconnection & Packaging Solutions* catalog is a description of Correct-a-Chip adapters, sockets, and semi-hybrid daughterboards. These products enable users to upgrade or further enhance existing products without costly redesign or board rework. The catalog lists typical applications or problems, which these product types can solve. Test heads for testing surface-mount pc boards without soldering the chip to the board are also covered. The catalog also describes Aries' range of test, programming, and burn-in sockets for accommodating a large variety of

styles and application needs, including the Universal ZIF socket, which accepts all seven standard PLCC packages. CM **CIRCLE 934**

PRODUCT TEST ACCESSORIES

Over 100 new products are included in the 1994 *New Product Test Accessories Catalog* from ITT Pomona Electronics, Pomona, Calif. The 36-page, free color catalog includes logic analyzer test accessories, IEC1010-safe probes, and banana jacks. Among the products highlighted are a new logic scope probe, insulated scope probes, oscilloscope probes, DMM test lead kits, IEC1010 probe leads, fused probe kits, grabbers, cable assemblies, and adapters. Also featured are test clips and adapters for the latest IC devices, including the MC68360, 80486SLE, and MC68HC11. Other products include boxes, test strips, and laboratory power supplies. CM **CIRCLE 935**



FAX-ON-DEMAND SERVICE

Eurotherm Controls, Reston, Va., now offers Fax-On-Demand for immediate transmission of sales and technical information to a fax machine. A library of over 75 data bulletins and technical information sheets concerning Eurotherm Controls products is available 24 hours a day. Fax-On-Demand is accessed by dialing 703-787-3441. First-time users can request a list of available documents. After that, users can order up to three documents in one transmission. Faxes are sent free of charge to any fax machine in the U.S. and Canada. CM **CIRCLE 936**

SOFTWARE SOLUTIONS

A 320-page catalog from Data Translation, Marlboro, Mass., describes the company's complete line of data-acquisition and imaging products. The 1994 handbook highlights software solutions from programming tools to applications and describes the company's extensive lines of high-performance and low-cost hardware. CM **CIRCLE 937**

UPCOMING MEETINGS

SEPTEMBER

Sensor Communication Standard Workshop (held in conjunction with Sensors Expo Technical Conference and Exhibition), Sept. 19. Cleveland IX Expo Center, Cleveland, OH. Contact Tammie Grice, National Institute of Standards in Technology, (301) 975-3883; fax (301) 948-2067.

14th IEEE International Semiconductor Laser Conference, Sept. 19-23. Hyatt Regency Maui, Maui, HI. Contact Samantha H. Phillips, IEEE/LEOS, 445 Hoes Ln., P.O. Box 1331, Piscataway, NJ 08855-1331; (908) 562-3894; fax (908) 562-1571; E-mail: s.phillips@ieee.org.

ASIC Conference and Exhibit (ASIC '94), Sept. 19-23. Rochester Riverside Convention Center, Rochester, NY. Contact Paul P.K. Lee, Eastman-Kodak Co., Rochester, NY 14650-2008; (716) 477-2869; fax (716) 477-4947.

AUTOTESTCON '94, Sept. 20-22. Disneyland Hotel, Anaheim, CA. Contact Robert Rassa, ManTech International, 150 S. Los Robles Ave., Suite 350, Pasadena, CA 91101; (818) 577-7100; fax (818) 577-7102.

Embedded Systems Conference, Sept. 20-23. Santa Clara Convention Center, Santa Clara, CA. Call (415) 905-2354 for more information.

Canadian Conference on Electrical and Computer Engineering, Sept. 25-28. World Trade & Convention Centre, Halifax, Nova Scotia. Contact C. Baird, Department of Electrical Engineering, Technical University of Nova Scotia, Post Office Box 1000, Halifax, Nova Scotia, B3J 2X4 Canada; (902) 420-7717; fax (902) 422-7535.

2nd IEEE Workshop on Interactive Voice Technology for Telecommunications Applications, Sept. 26-27. Sumitomo Hall, Kyoto, Japan. Contact Sadaoki Furui, NTT Human Interface Labs, 3-9-11 Midori-cho, Musashino-shi, Tokyo, 180 Japan; 81-422-59-3910; fax 81-422-60-7808.

Information Superhighway Summit/San Jose, Sept. 26-28. Red Lion Hotel, San Jose, CA. Contact Jeff Silha, IDG World Expo, (800) 225-4698 or (508) 820-8628.

WESCON '94-Idea/Microelectronics, Sept. 27-29. Anaheim Convention Center, Anaheim, CA. Contact Joan Carlisle, Electronic Conventions Management, 8110 Airport Blvd., Los Angeles, CA 90045; (310) 215-3976; fax (310) 641-5117.

3rd International Conference on Universal Personal Communications, Sept. 27-Oct. 1 (ICUPC '94). San Diego, CA. Contact Henry A. Macchio, Hughes Network Systems Inc., 10450 Pacific Center Ct., San Diego, CA 92121; (619) 452-4610; fax (619) 597-8979.

OCTOBER

MILCOM '94, Oct. 1-5. Fort Monmouth, NJ. Contact Donald L. Schilling, InterDigital Communications Corp., 85 Old Shore Rd., Suite 200, Port Washington, NY 11050; (516) 883-0760; fax (516) 883-0746.

1994 IEEE International Test Conference (ITC), Oct. 2-6. Sheraton Washington Hotel, Washington D.C. Contact Doris Thomas, International Test Conference, 205 Tennyson Ave., Suite C, Altoona, PA 16602; (814) 941-4666; fax (814) 941-4668.

Antenna Measurement Techniques Symposium '94, Oct. 3-7. Hyatt Regency, Long Beach, CA. Contact James P. McKay, The Aerospace Corp., M1/135, P.O. Box 92957, Los Angeles, CA 90009; (310) 336-1596; fax (310) 336-6225.

Far East Tour 1994, Electronics & Computer Shows, Oct. 4-17. Japan, Taiwan, Hong Kong, Korea, China, Singapore. Contact Ellen Wong, Commerce Tours International Inc., 870 Market St., S San Francisco, CA 94102; (415) 433-3072; fax (415) 433-2820.

CD-ROM Expo/Boston, Oct. 5-7. World Trade Center, Boston, MA. Contact Mitch Hall & Associates at (617) 361-2001.

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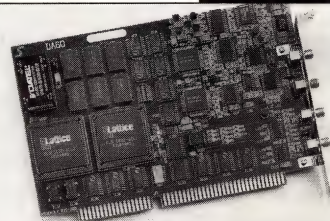
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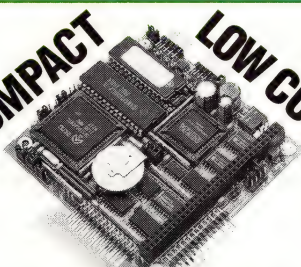
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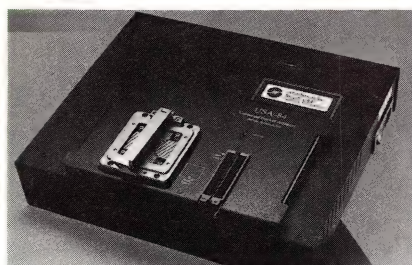
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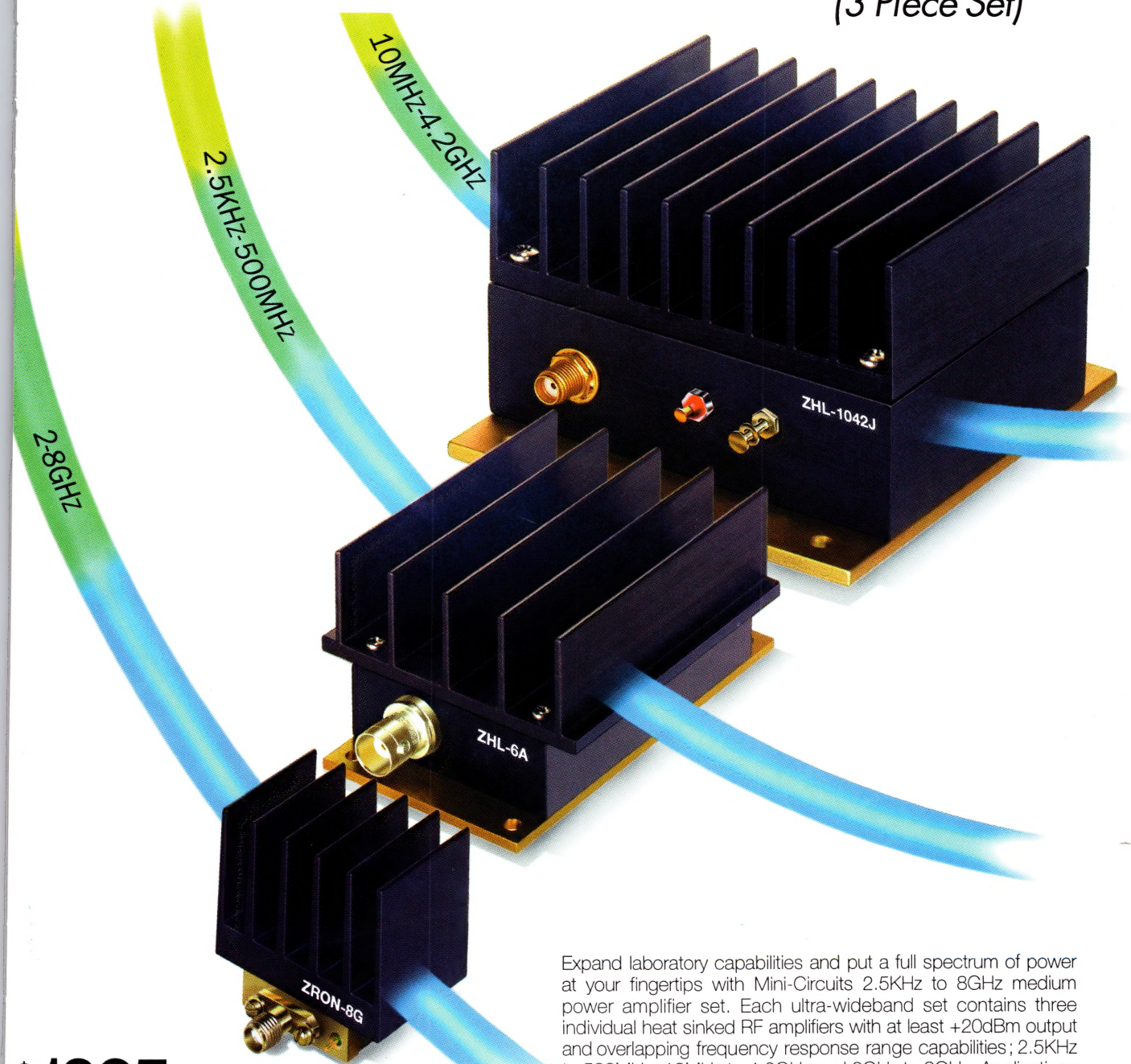
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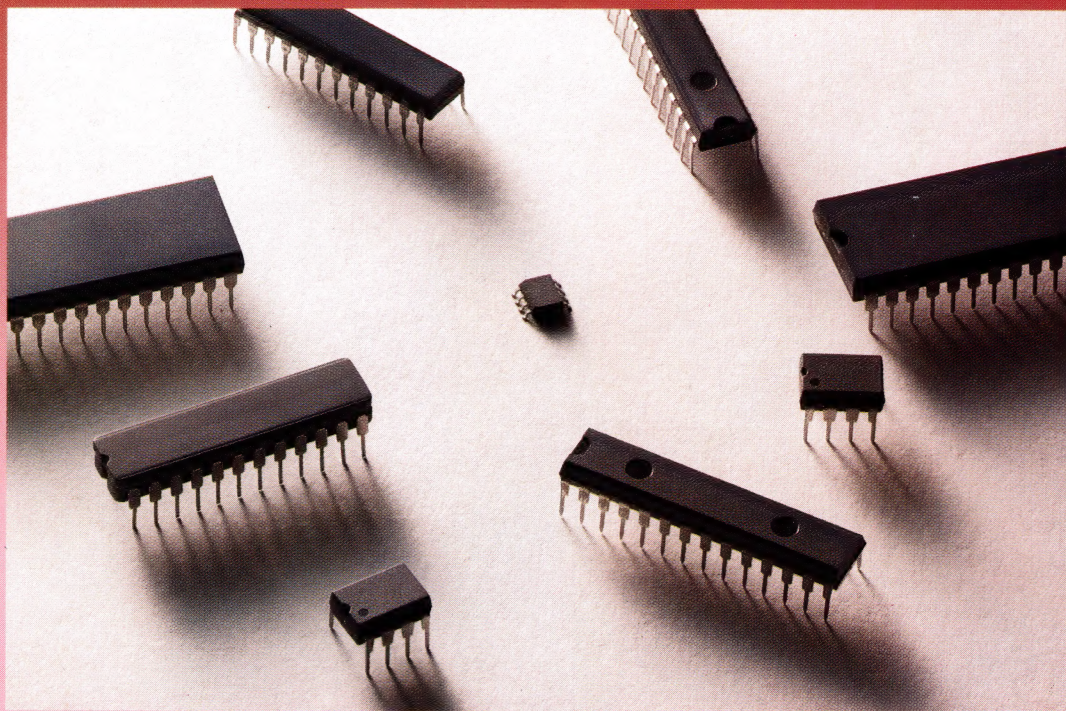
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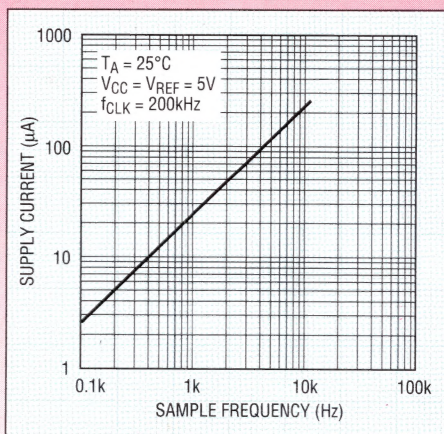


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